

Flight Readiness Review
13 MAR 15



Navy Rockets*
United States Naval Academy
Annapolis, Maryland

* 1/C Midshipmen Capstone, Aerospace Engineering Department

Team Mission

The mission of Navy Rockets is to provide an expansion and application of classroom knowledge through a unique project based engineering opportunity. Navy Rockets also strives to develop members morally and mentally by imbuing them with the highest ideals of engineering leadership and practice. During this year's Student Launch program, Navy Rockets will deliver a rocket and ground support element that incorporates a payload delivery system that meets all required criteria as defined by NASA and Centennial Challenges guidelines. Overall, Navy Rockets is committed to excellence in practice, delivery, and conduct.

Navy Rockets Charter

The vision of Navy Rockets is to:

- *Supplement academic material in both the aerospace and engineering fields*
- *Expand each midshipmen's knowledge and experience to become more proficient and well-rounded members of the engineering community*
- *Provide leadership opportunities in a technical environment to better serve midshipmen as future leaders in today's Navy*

As a team we strive to:

- *Seek out projects that can benefit the aerospace community and reinforce our own educational objectives*
- *Deliver quality research and products on time, based in sound engineering and business practices, and operate to a level above client expectation*

As representatives of the armed services we will:

- *Conduct ourselves in a professional manner and bring credit to both the United States Naval Academy and the United States Naval service.*

We are **committed to excellence** in practice, delivery, and conduct.

Table of Contents

Team Mission.....	1
Navy Rockets Charter	1
List of Figures	6
List of Tables	8
List of Abbreviations	9
1 Flight Readiness Review.....	10
1.1 Team Summary	10
1.2 Launch Vehicle Summary	10
1.3 AGSE Summary	10
1.4 Team Members.....	11
2 Changes to the Critical Design Review	12
2.1 Vehicle.....	12
2.1.1 Payload	12
2.1.2 Recovery.....	13
2.1.2.1 Ejection Canisters	13
2.1.2.2 Wiring Diagram.....	13
2.2 AGSE.....	14
2.3 Project Plan.....	14
2.4 Suggested Changes.....	14
3 Vehicle Criteria	15
3.1 Launch Vehicle.....	15
3.1.1 Requirements.....	15
3.1.2 Vehicle Success Criteria.....	15
3.1.3 Subsystem Success Criteria.....	15
3.1.4 Flight Profile.....	16
3.2 Design and Construction	17
3.2.1 Structural Elements	20
3.2.1.1 Material Selection	20
3.2.1.2 Body Tubes	22
3.2.1.3 Motor Mount.....	26
3.2.1.4 Section Securement.....	27
3.2.2 Electrical Elements.....	28
3.2.3 Assembly	28
3.2.4 Full-scale Testing	28
3.2.5 Workmanship	29
3.2.6 Safety and Failure Analysis.....	29
3.2.7 Mass Statement.....	30

3.3	Payload Securement Subsystem.....	31
3.3.1	Structural Elements	32
3.3.2	Electrical Elements.....	33
3.3.3	Assembly	35
3.3.4	Component Testing	35
3.3.5	Safety and Failure Analysis.....	35
3.4	Recovery Subsystem	36
3.4.1	Structural Elements	36
3.4.2	Parachute Characteristics	38
3.4.3	Electrical Elements.....	39
3.4.4	Recovery Schematic	41
3.4.5	GPS Transmitters	42
3.4.6	Recovery Testing.....	43
3.4.7	Safety and Failure Analysis.....	44
3.5	Propulsion.....	44
3.5.1	Final Rocket Motor Selection.....	44
3.5.2	Motor Mount Design	47
3.5.3	Flight Reliability and Confidence	48
3.6	Mission Performance Predictions.....	48
3.6.1	Performance Criteria	48
3.6.2	Subscale Flight Results	48
3.6.3	Flight Simulations	49
3.6.4	Rocket Stability	52
3.6.5	Kinetic Energy.....	53
3.6.6	Drift Analysis	54
3.7	Vehicle Verification	57
3.7.1	Wind Tunnel Testing.....	57
3.7.1.1	Nose Cone.....	57
3.7.1.2	Body Section	57
3.7.1.3	Fin Section	57
3.7.1.4	Testing	58
3.7.1.5	Results	58
3.7.1.6	Analysis	59
3.7.2	Requirement Verification.....	59
3.8	Vehicle Safety	59
3.8.1	Safety Analysis.....	59
3.8.2	Personnel Hazards	60
3.8.3	Environmental Concerns	61
3.9	AGSE Integration	61
3.9.1	Integration Plan	61
3.9.1.1	Payload to Rocket Body.....	61

3.9.1.2	Vehicle to Ground Interface	62
3.9.2	Element Compatibility	62
3.9.3	Housing Integrity	62
4	AGSE Criteria	64
4.1	Science Value	64
4.1.1	AGSE Objectives	64
4.1.2	AGSE Mission	64
4.1.3	Mission Success Criteria	64
4.1.4	AGSE Experimental Approach	65
4.1.5	Variable Control	65
4.2	AGSE Design	66
4.2.1	Tower Structure	66
4.2.2	Tower Motor and Amplifier	68
4.2.3	Tower Sled	69
4.2.4	Scorbot ER-V	71
4.2.5	Igniter Insertion Device	72
4.3	AGSE Configuration	73
4.3.1	Assembly	75
4.3.2	Instrument Precision	75
4.4	Testing and Verification Plans	75
4.5	AGSE Integration	77
4.5.1	Integration Plan	77
4.5.2	AGSE Timeframe	79
4.6	Verification	79
4.6.1	Requirement Verification	79
4.7	AGSE Safety	80
4.7.1	Safety Analysis	80
4.7.2	Personnel Hazards	81
4.7.3	Environmental Concerns	81
5	Launch Operations	82
5.1	REPTAR Checklists	82
5.1.1	Pre-flight Brief	82
5.1.2	Recovery Preparation	83
5.1.3	Motor Preparation	83
5.1.4	AGSE Assembly Setup	83
5.1.5	Launcher Setup	84
5.1.6	Igniter Installation	84
5.1.7	Launch Procedure	85
5.1.8	Troubleshooting	85
5.1.9	Post-flight Inspection	86
5.2	Safety and Quality Assurance	86
5.2.1	Safety and Quality Inspector	86
5.2.2	Safety Analysis	86
5.2.2.1	Laws	86

5.2.2.2	MSDS	87
5.2.3	Operational Risk Management.....	87
5.2.4	Personnel Hazards	94
5.2.5	Environmental Concerns	97
6	Project Plan	100
6.1	Budget Plan	100
6.2	Funding Plan.....	102
6.3	Timeline.....	102
6.4	Educational Engagement.....	104
6.4.1	STEM Coordination	104
6.4.2	Team Participation	105
6.4.3	STEM events	105
6.4.3.1	MESA DAY	105
6.4.3.2	Mini-STEM	106
6.4.3.3	Girls-Only STEM Day	106
6.4.3.4	Space Exploration Merit Badge	106
6.4.4	Sustainability	106
6.4.4.1	Major Sustainability Challenges and Solutions.....	107
6.4.5	Educational Engagement Progress (Proposal to CDR)	107
6.4.6	Outreach Update.....	108
7	Conclusion	109
	APPENDIX A: FRR Flysheet.....	110
	APPENDIX B: Component Sizing	112
	APPENDIX C: Wind Tunnel Test Plan.....	114
	APPENDIX D: Mission Requirements.....	120
	APPENDIX E: Laws and Safety Codes.....	127
E.1	NAR High Power Rocket Safety Code	127
E.2	TRA Code for High Power Rocketry.....	129
E.3—	Amateur Rockets Laws	133
E.4	Law & Regulations: NAR.....	135
	APPENDIX F: MSDS.....	140
	APPENDIX G: Gantt Chart	184

List of Figures

Figure 1. Flight Profile.....	17
Figure 2. OpenRocket Design and Solid Works Model	18
Figure 3. Rocket Dimensions.....	19
Figure 4. Fin and Motor Dimensions.....	20
Figure 5. Full Scale Rocket.....	20
Figure 6. Body Tube Molds (48 inches)	22
Figure 7. Body Tube Mold Lip	23
Figure 8. Tubing Mold Shape (Half Circle).....	23
Figure 9. Tubing Connections (Full Circle).....	24
Figure 10. Avionics Flange Window (Open and Closed).....	24
Figure 11. Nose Cone Mold Halves.....	25
Figure 12. Nose Cone Mold Final Construction	25
Figure 13. Mount Mount.....	26
Figure 14. Motor Retention System.....	27
Figure 15. PVC Couplers (Installed)	27
Figure 16. Full Scale Rocket during Launch.	28
Figure 17. DC Motor and Gearing System	33
Figure 18. Payload Section Electrical Schematic	33
Figure 19. Arduino Micro in Testing Configuration	34
Figure 20. Recovery Harness Attachment Points	37
Figure 21. Drogue Attachments in Motor Tube.....	38
Figure 22. Black Diamond Positron Screw gate Carabineer	38
Figure 23. Recovery Electronics Schematic	39
Figure 24. Ejection Canisters on Avionics Section	40
Figure 25. The Launch Vehicle in Recovery Configurations after Ejection Event 1 (left) and Ejection Event 2 (right).....	42
Figure 26. Recovery Test Stand.....	43
Figure 27. K600 Vertical Motion vs. Time.....	45
Figure 28. K750 Vertical Motion vs. Time.....	45
Figure 29. K1200 Vertical Motion vs. Time.....	46
Figure 30. K1200 Thrust and Vertical Motion vs. Time	47
Figure 31. Half Scale Rocket Launch	49
Figure 32. Vertical Motion vs. Time at 5 mph	50
Figure 33. Vertical Motion vs. Time at 10 mph	50
Figure 34. Vertical Motion vs. Time at 15 mph	51
Figure 35. Vertical Motion vs. Time at 20 mph	51
Figure 36. K1200 Stability Margin and Angle of Attack vs. Time	52
Figure 37. Lateral Wind Drift vs. Wind Speed for the Best and Worst Case Scenarios	55
Figure 38. Surface Plot of Wind Drift with Respect to Direction and Speed	56
Figure 39. Payload Housing.....	63

Figure 40. Tower Foot with Milled Coupler and Flange Bearing	66
Figure 41. Ladder Design of Tower Structure	67
Figure 42. AGSE Loading Configuration	68
Figure 43. AGSE Launching configuration	68
Figure 44. Motor Mount Drawing	69
Figure 45. Tower Sled.....	69
Figure 46. Sled Connector	70
Figure 47. Top-down View of Scorbot Operating Range	71
Figure 48. Side View of Scorbot Operation Range	71
Figure 49. Igniter Insertion Drawing	72
Figure 50. Un-mounted Igniter Insertion System	73
Figure 51. Scorbot ER-V	74
Figure 52. Payload Tube	76
Figure 53. AGSE Schematic	78
Figure 54. ORM Values.....	88
Figure 55. ORM Risk Matrix.....	88

List of Tables

Table 1. Subsystem Criteria.....	16
Table 2. Material QFD.....	21
Table 3. Launch Vehicle Failure Modes.....	29
Table 4. Component Masses.....	30
Table 5. Payload Section Failure Analysis	35
Table 6. Black Powder Charge Calculations	41
Table 7. GPS Characteristics**	43
Table 8. Mass of Sections During Flight	53
Table 9. Kinetic Energy Values for Sections.....	54
Table 10. Wind Drift Values at the Best and Worst Case Scenarios	55
Table 11. C_D Values from Wind Tunnel.....	59
Table 12. Vehicle Safety Analysis.....	60
Table 13. Personnel Hazards.....	61
Table 14. Success Criteria.....	65
Table 15. AGSE Timeframe	79
Table 16. Failure Modes and Effects Analysis	80
Table 17. AGSE Personnel Hazards	81
Table 18. Hazard Analysis for Project and Safety	89
Table 19. Hazard Analysis for Vehicle Safety.....	91
Table 20. Hazard Analysis for the AGSE System	94
Table 21. Hazard Analysis for the Student Launch Project.....	95
Table 22. Safety Concerns for the Student Launch	96
Table 23. Environmental Impact on the Rocket	97
Table 24. Rocket Impact on the Environment	99
Table 25. Navy Rockets Comprehensive Budget	100
Table 26. Full-Scale Itemized Budget	101
Table 27. Navy Rockets' Funding Plan.....	102
Table 28. Milestone Schedule.....	102
Table 29. Project Punch List.....	103
C-1. Wind Tunnel Test Personnel.....	116

List of Abbreviations

AGL	Above Ground Level
AGSE	Autonomous Ground Support Equipment
AIAA.....	American Institute of Aeronautics and Astronautics
BSA.....	Boy Scouts of America
CG.....	Center of Gravity
CNC	Computer Numerical Control
CP.....	Center of Pressure
DARPA	Defense Advanced Research Projects Agency
E-glass.....	Fiberglass
FAA.....	Federal Aviation Administration
GET IT and GO	Girls Exploring Technology through Innovative Topics, Girls Only
GSE	Ground Support Equipment
GNC	Guidance, Navigation, Control
GPS	Global Positioning System
HDF.....	High Density Foam
IMSAFE	Illness, Medications, Stress, Alcohol, Fatigue, Eating
ISR	Intelligence, Surveillance, and Reconnaissance
MATLAB.....	Matrix Laboratory
MDRA.....	Maryland Delaware Rocketry Association
MESA	Maryland Mathematics Engineering Science Achievement
MSL	Mean Sea Level
MURS	Multiuse Radio Service
NAR	National Association of Rocketry
NASA.....	National Aeronautics and Space Administration
NESA	National Eagle Scout Association
PVC.....	Polyvinyl Chloride
QFD.....	Quality Function Deployment
REPTAR	Rocket Equipped Payload Transportation and Autonomous Release
RSO.....	Range Safety Officer
S-glass	Stiff Fiberglass
SRQA.....	Safety, Reliability, and Quality Assurance
STEM.....	Science, Technology, Engineering, and Mathematics
TRA.....	Tripoli Rocketry Association
VTC.....	Video-conferencing and communication
USLI.....	University Student Launch Initiative
USNA.....	United States Naval Academy
USNA MSTEM	United States Naval Academy Midshipmen Science, Technology, Engineering, and Mathematics

1 Flight Readiness Review

1.1 Team Summary

Team Name: Navy Rockets

Institution: United States Naval Academy

Mailing Address: Aerospace Engineering Department
United States Naval Academy
ATTN: NASA Student Launch Capstone
Mail Stop 11B
590 Holloway Road
Annapolis, MD 21402-5042

Project Mentor: Robert Utley (NAR Level 3)
NAR # 71782 TRA # 6103
President, Maryland Delaware Rocketry Association

*Due to other commitments, Robert Utley will not be able to attend. However, Robert DeHate, another team's mentor, will be able to assist Navy Rockets if required. Navy Rockets' Safety Officer, Cole, who is a TRA Level 2 will be responsible for the rocket and motor.

1.2 Launch Vehicle Summary

The REPTAR launch vehicle will be 108 inches tall with a 5 inch diameter launching off of a Cesaroni K1200 motor. The rocket will utilize a redundant dual deployment system upon the recovery stage of flight. This system includes two identical PerfectFlite Stratologger altimeters and four black powder ejection charges. Upon apogee, both altimeters will simultaneously trigger two aft facing ejection charges, pressurizing the aft recovery compartment and releasing an 24 inch elliptical drogue parachute. Then, at an altitude of 1000 feet AGL, the altimeters will trigger a second ejection event in the forward recovery compartment. This event will pressurize the compartment and jettison the forward payload section of the launch vehicle. The main body will deploy a 72 inch torroidal parachute and the payload section will deploy a 60 inch torroidal parachute. The Flysheet for the rocket can be found in Appendix A.

1.3 AGSE Summary

Project Title: REPTAR (Rocket Equipped Payload Transportation and Autonomous Release) System

The Autonomous Ground Support Equipment is designed to insert the payload with the use of a Scorbot ER-V and remotely secure the payload within the payload compartment. Following this, the AGSE will move the rocket from a horizontal loading position to the final launch position, which is 5 degrees from the vertical plane. Upon placement of the rocket into the launch position, the AGSE will insert the rocket motor igniter. Once the igniter has been inserted, the rocket will launch off of the 10 foot launch rail. All AGSE tasks will be issued from a laptop computer through RF transmitter and receiver units. The entire sequence will be completed from start to finish within a 10 minute window.

1.4 Team Members

Team Size: 9 Midshipmen

Hayes (Astronautical Engineering, '15)

- Team Manager
- GNC (Guidance, Navigation, Control) / Recovery System Chief
- Systems Engineering/Integration Chief

Alex (Astronautical Engineering, '15)

- Administrative Officer
- Chief Engineer
- Drafting Chief
- Avionics Chief

Cole (Aeronautical Engineering, '15)

- Document Manager
- Safety Administration Officer
- SRQA (Safety Reliability & Quality Assurance) Chief
- Materials/Structures Chief

Joe (Astronautical Engineering, '15)

- Technology Officer
- Propulsion Chief

Richie (Astronautical Engineering, '15)

- Financial Officer
- GSE (Ground Support Equipment) Chief

Thor (Astronautical Engineering, '15)

- Acquisitions Officer
- Payload Design Chief

Sam (Astronautical Engineering, '15)

- AGSE Coding Chief
- Tower Erection Lead

Troy (Aeronautical Engineering, '15)

- Public Affairs/ Outreach Officer
- Aerodynamics Chief

Andy (Astronautical Engineering, '16)

- Project Assistant
- Igniter Insertion Lead

2 Changes to the Critical Design Review

2.1 Vehicle

The overall rocket length changed from 103 inches to 108 inches. During the building process the sections were cut slightly longer than first planned so that the sections could be tested. While verifying if everything would fit properly it was determined that 5 additional inches would be required to ensure that none of the equipment was damaged. By jamming equipment into the rocket it causes a safety concern and potential failure mode however it was fixed by this increased length.

The rocket body tube mold originally had its own coupler built into the tube. The idea was that each piece would have a 4 inch shoulder that was one continuous piece of tubing. However, while attempting to connect sections together the designed couplers did not fit perfectly inside the other tubes. This was corrected by cutting off these couplers and epoxying in couplers made from PVC. The PVC couplers were lathed down to fit the inner diameter of the tubes and allow for separation.

Another change was to the fin and bulkhead material. This was originally going to be made from carbon fiber; however, G10 Epoxy Glass was used. The G10 Epoxy Glass is very strong and durable and is easily able to withstand the forces applied during launch. This material is pre-fabricated so also allowed for a quicker build process.

2.1.1 Payload

A change to the launch vehicle payload section has been the selection of a new DC motor that drives the rack and pinion system. Previously at CDR, a Pololu Micro Metal Gearmotor HP had been selected. Now, Navy Rockets will be using an Actobotics 32 RPM Precision Planetary Gearmotor. This new selection was made to ensure better mechanical fit and operation of the motor within the payload section. Additionally, this motor is more powerful than the previously selected motor, which will ensure that the motor has enough power to properly address any contingencies.

A second change to the payload section is the use of one-quarter inch threaded steel rods instead of three-eighths inch aluminum rods for supports in the payload section. This change was made to facilitate easier installation and maintenance of the payload section components, while still remaining strong and light as support rods.

2.1.2 Recovery

2.1.2.1 Ejection Canisters

Previously, Navy Rockets has employed the use of pre-fabricated ejection canisters with installed resistive e-matches. These canisters, although convenient and easy to use, typically were not capable of holding enough black powder for effective separation of rocket sections. This often required the use of multiple canisters per separation event, especially with redundant charges.

Pre-fabricated ejection canisters were difficult to arrange within the section, and typically laid in close proximity to one another. Occasionally, the heat generated by the combustion of the primary charge would cause the secondary charge to combust prematurely. This created over-pressure within the pressurized section, which could result in a separation of the section from the recovery harness or parachute.

Therefore, Navy Rockets has installed four permanent ejection charge receptacles on the two bulkheads of the avionics section. These receptacles, which are each a two inch length of $\frac{3}{4}$ inch PVC pipe, will be filled with the appropriate amount of black powder, topped off with traditional paper wadding, and capped with wind tunnel Mach tape.

2.1.2.2 Wiring Diagram

After reassessment of the redundancy in our system, Navy Rockets determined that a common point of failure was present in electrical configuration of the primary and secondary altimeters. PerfectFlite StratoLoggers are still being employed, but they will be wired to electrically independent screw-top terminals on the outside of the avionics section bulkheads. This will create true redundancy throughout the entire altimeter system.

The primary altimeter will be programmed to initiate a charge intended to deploy a drogue parachute at flight apogee, then initiate a charge intended to simultaneously separate the sample section and deploy a main parachute at 1000 feet above ground level. The secondary altimeter will be programmed to initiate a charge intended as a backup to the first primary altimeter charge. This event will occur 3 seconds after flight apogee. The secondary altimeter will then initiate a charge intended as a backup to the second primary charge. This event will occur at 900 feet above ground level.

2.2 AGSE

- 1) The joints between the horizontal and vertical components of the tower feet have been reinforced with triangular aluminum plating. This will ensure that the welds will not crack if a moment is exerted upon the structure during any portion of the sequence.
- 2) The sled will have two wheels on the lower end, as opposed to one. The tower structure will have to two tracks, one for each wheel. This will increase the stability of the sled as it is raised to the launch position.
- 3) The battery has been changed to a 12 volt, 75 AH battery. The increase in capacity will increase the possible loiter time.
- 4) Rungs are no longer pinned into place. The upper and lower rungs are mounted onto flange bearings to facilitate rotation. Middle three rungs are welded into place for maximum stability.
- 5) The Scorbot shield has been removed from the design.
- 6) Number of tests for everything has been reduced to 10 iterations, with the exception of the Scorbot with a dummy payload and dummy payload bay. The number of repetitions required before these changes were excessive and time consuming.

2.3 Project Plan

No plans have changed since CDR.

2.4 Suggested Changes

An additional switch was added to the avionics section to ensure redundant systems while controlling the altimeters.

3 Vehicle Criteria

3.1 Launch Vehicle

3.1.1 Requirements

The key requirements in this year's NASA Student Launch competition are as follows:

- Launch Vehicle:
 - Payload Sample Containment System
 - Active GPS tracking
 - Launch to 3000 feet AGL
 - Jettison payload section at 1000 feet AGL
 - Return both sections to ground with under 75 ft-lb KE
- Autonomous Ground Support Equipment (AGSE):
 - Retrieve sample and place inside horizontal launch vehicle
 - Erect launch vehicle to 5° from vertical
 - Insert electronic igniter into motor
 - Include pause function
 - No human interaction or commands sent once process begins
- Neither deliverable may cost over \$5,000, for a total of \$10,000

3.1.2 Vehicle Success Criteria

In order for this year's REPTAR project to be a success, Navy Rockets will deliver an autonomous ground support element capable of loading the specified payload into a rocket, launch the rocket to 3000 feet AGL, and return both the main rocket body and the jettisoned payload section safely to the ground while meeting all specified mission criteria listed above.

3.1.3 Subsystem Success Criteria

The REPTAR launch vehicle has multiple subsystems and components that work into the design as shown in Table 1.

Table 1. Subsystem Criteria

Subsystem	Description	Function
Payload	The design, construction, and testing of payload sample integration and associated recovery system.	Shall integrate and retain the sample into the rocket body and deliver it safely back to the surface
Materials and Structures	The design, validation, construction, and testing of the materials and dimensions used in the rocket body, fins, and nosecone.	Shall effectively support and retain all internal hardware from both atmospheric and internal effects, and maintain structural integrity from launch to landing.
Flight Avionics	The selection and integration of all GPS systems and flight data recorders, as well as associated power systems.	Shall provide real-time tracking of the vehicle's position after launch as well as provide the flight data for SL and Centennial scoring judges.
Recovery	The design, selection, and testing of the parachute and associated components for both the payload and main body sections.	Shall safely deliver both the payload and main body sections back to the ground in a timely and controlled manner, while allowing both to maintain their structural integrity.
Propulsion	The selection and calculation of the motor size and manufacturer to meet the flight requirements based on the vehicle design.	Shall deliver the vehicle to the prescribed altitude and provide the initial phase of the recovery system in a controlled manner.

3.1.4 Flight Profile

The rocket will follow a planned flight path. This path will include apogee at 3000 feet and deployment of the drogue and payload at 1000 feet. The flight plan can be seen in Figure 1.

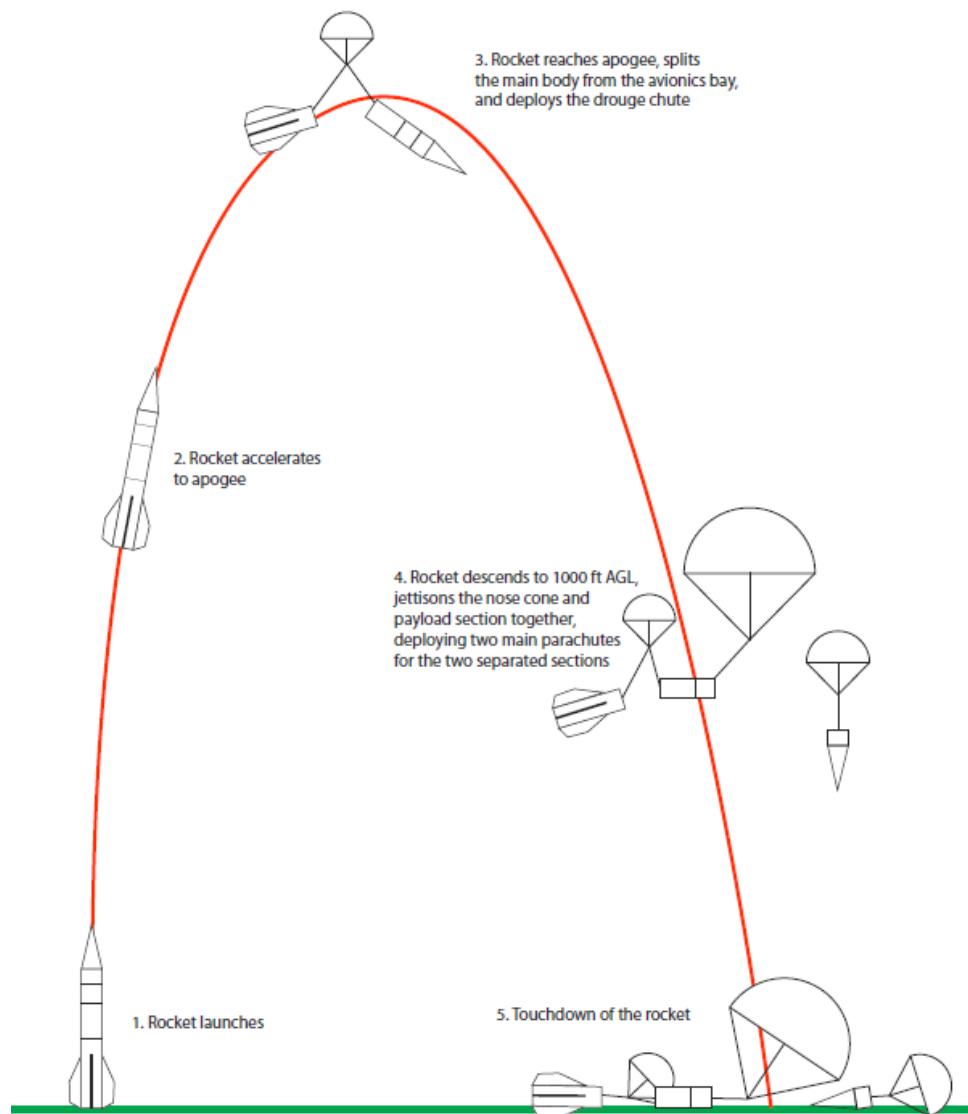


Figure 1. Flight Profile

3.2 Design and Construction

The rocket is 5 inches in diameter and 108 inches long made from both carbon fiber and fiberglass. The entire structure has a constant thickness of 0.08 inches thick. The nose cone and avionics section, shown in Figure 2, hold electronic equipment and is made from fiberglass and high strength honeycomb foam. The nose cone is 26 inches long, shown in Figure 3, and will

hold the payload section's GPS and cover the sample payload. The avionics section will hold the main body's GPS and altimeters.

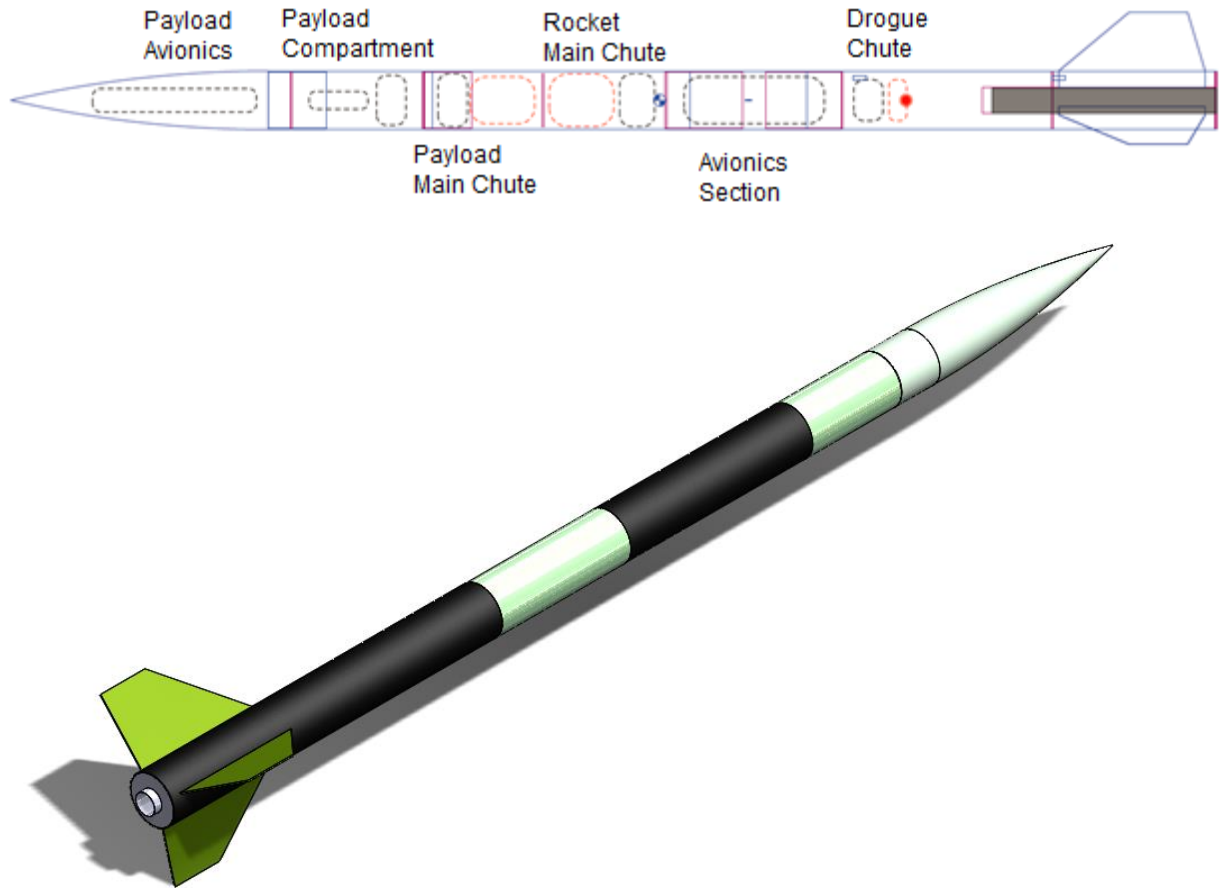


Figure 2. OpenRocket Design and Solid Works Model

The rest of the rocket body is made from carbon fiber. The payload compartment will be 10 inches long and hold the mechanical equipment that will control the payload system. The parachutes are housed in a 20.5 inch long section with the entire recovery harnesses for both the payload and the main body. The avionics section of the rocket will be 14.5 inches long. The lower section of the rocket will be 37 inches long and hold the motor casing and motor retention. The motor mount will be 25 inches long and 54 millimeters in diameter, shown in Figure 4, in order to accommodate the correct motor.

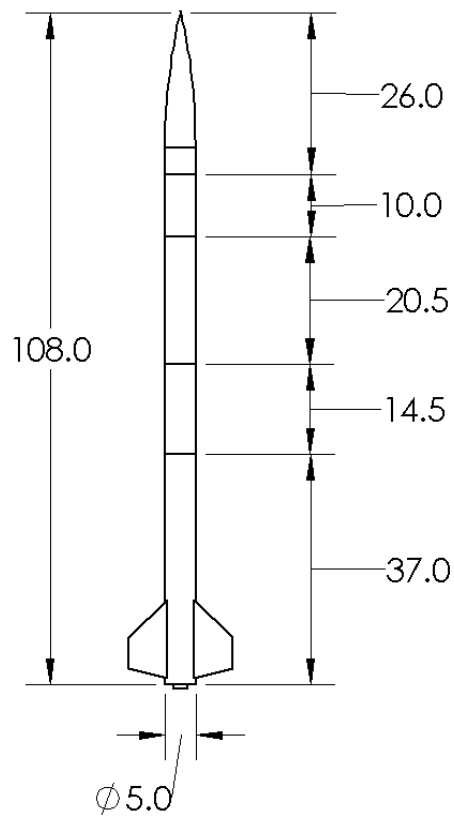


Figure 3. Rocket Dimensions

The three fins are connected to the motor mount and held between centering rings. The fins are 0.125 inches thick and have an area of 47.5 square inches. The complete component sizes can be found in Appendix B and the completed rocket can be seen in Figure 5.

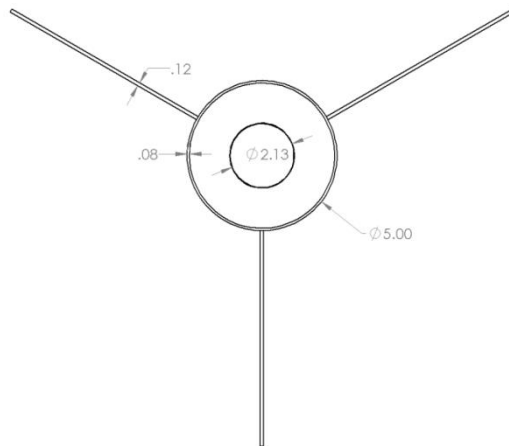


Figure 4. Fin and Motor Dimensions



Figure 5. Full Scale Rocket

3.2.1 Structural Elements

3.2.1.1 Material Selection

Carbon fiber and fiberglass are common materials used in high power rocketry. In order to determine which material is the better product a house of quality is used. The house of quality

uses the Quality Function Deployment System (QFD) as seen in Table 2. The QFD system allows the two materials to be tested on important characteristics for the project. Each characteristic has a weighting of importance for the project; a one weighting represents little importance to the project, a three weighting represents medium importance, and a nine weighting means that it is critical to the project. This weighting allows the important factors to outweigh less desired characteristics. If the material agreed with the material factor it was given a positive weighting score. If the material completely disagreed it was given a negative weight score. A score of zero was given when the material met the requirements but did not stand out against the other.

Table 2. Material QFD

Material Factors	Weighting Factor	Materials	
		Carbon Fiber	Fiberglass
Low cost	3	-3	3
High availability	3	3	3
Compact rocket size	9	9	-9
Low weight	9	9	-9
Easy production	9	-9	-9
High tensile strength	1	1	1
High compressive strength	9	9	0
High stiffness	3	3	0
High heat resistance	3	3	3
High Young's modulus	3	3	0
Large motor selection	9	9	0
Totals		37	-17

Carbon fiber was selected for its superior material strength, low weight, and relatively high availability. Although the cost of carbon fiber was significantly higher than alternative materials, such as fiberglass and cardboard, the cost difference was not significant enough to push the design out of budget. Due to the low density of carbon fiber, the dimensions of the rocket were able to be greatly reduced, as well as the motor size required to push the rocket to 3,000 feet in altitude. Using carbon fiber for a majority of the rocket allows for level K motors to be used whereas it would require an L motor to power a fiberglass rocket to the same altitude. Carbon fiber will be used throughout the body to save on weight and increase the strength of the rocket. In the avionics section and the nose cone, the rocket will be made from fiberglass. The fiberglass is strong enough to endure the forces during a flight but it also allows signal to

transmit. Using fiberglass throughout the entire body would greatly increase the weight and decrease the strength for the thickness of the material.

3.2.1.2 Body Tubes

The rocket consists of both carbon fiber and fiberglass materials. The process of constructing the rocket with carbon fiber and fiberglass has been taught to the team by a composite specialist from the Machine Shop in Rickover Hall. This specialist also supervised the manufacturing process in order to ensure that the components come out correctly. For the body tube, two circle in-lay molds has been extruded from high density foam, shown in Figures 6 and 7.



Figure 6. Body Tube Molds (48 inches)

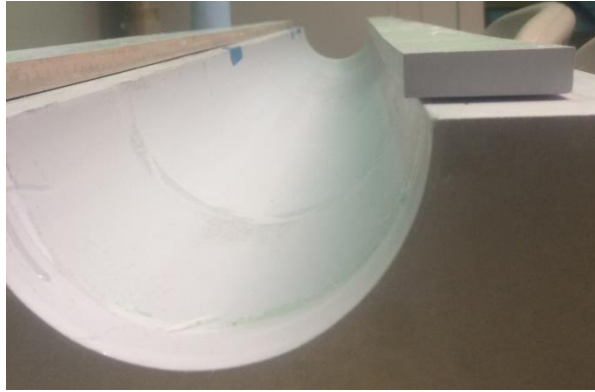


Figure 7. Body Tube Mold Lip

The two half circles slightly overlap each other with a small lip and come to a small taper at each end. This lip allows each piece of the tube to interlock with the opposite side as shown in Figures 8 and 9. When producing the tubes, a quick release agent was applied to the inside of the mold and then the material will be laid and secure with epoxy. Once the materials were correctly laid it then underwent vacuum bagging to help the material set properly.

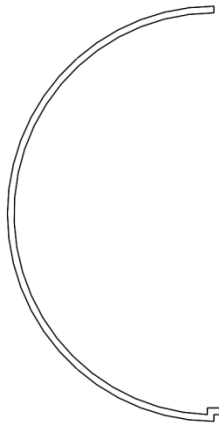


Figure 8. Tubing Mold Shape (Half Circle)

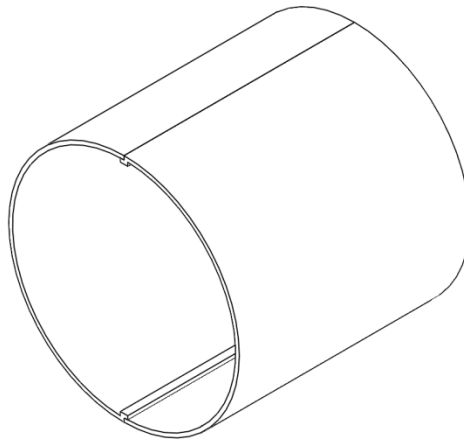


Figure 9. Tubing Connections (Full Circle)

For the carbon fiber, the connection points of the tubing have an additional layer of carbon fiber to secure them. For the fiberglass sections, the overlapped areas were epoxied together. A window was cut out of the main electronics section that allows a panel to be removed and allow access to the components. A fiberglass flange, shown in Figure 10, was created using the tube mold then epoxied internally to allow the window to rest on the edges.



Figure 10. Avionics Flange Window (Open and Closed)

The fins and bulkheads, which are be 0.125 inches thick, created by using G10 Epoxy Glass. This material is fabricated to have a high mechanical strength. The nose cone was created by an extruded foam mold of two halves of the nose cone, shown in Figures 11 and 12. Once both halves were created they were epoxied together and secure with additional fiberglass strips.

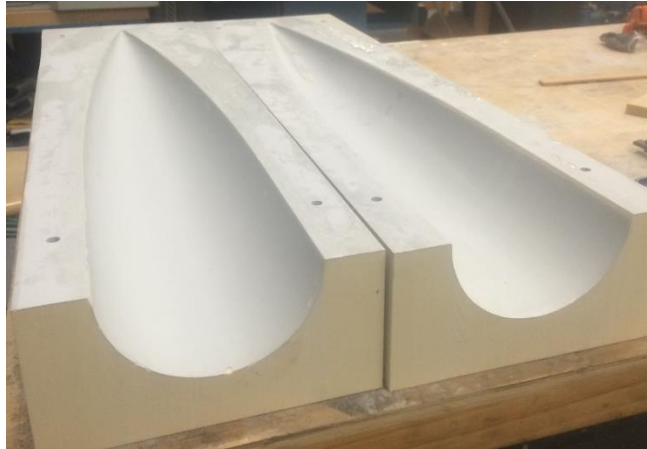


Figure 11. Nose Cone Mold Halves

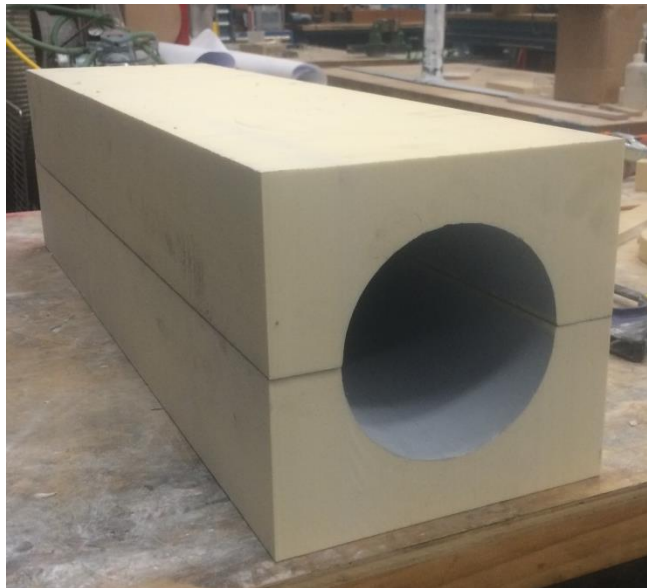


Figure 12. Nose Cone Mold Final Construction

3.2.1.3 Motor Mount

The motor mount for the rocket was created from a smaller carbon fiber tube that has an inner diameter equivalent to the motor retention tube. The mount has two centering rings, one on both ends of the tube to ensure the tube was completely centered while it was inserted into the rocket. Each centering ring is 0.125 inches thick of the G10 Epoxy Glass. The motor mount can be seen in Figure 13.

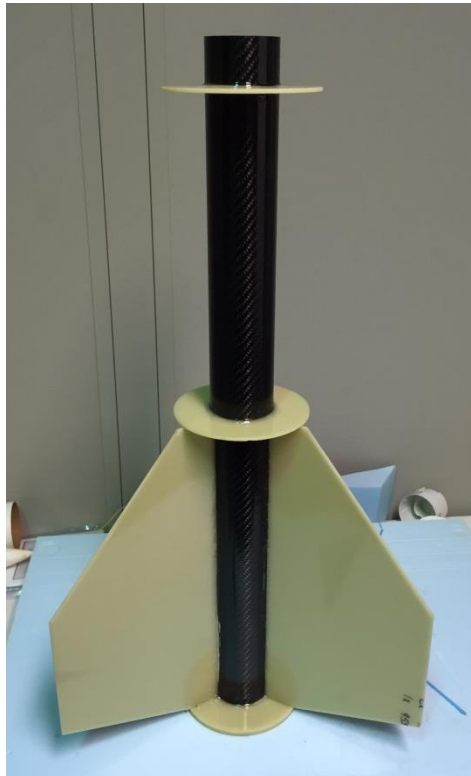


Figure 13. Mount Mount

The carbon fiber tube will hold the motor and its casing and at the bottom end be secured by a twist on bolt for a cap to ensure that the motor does not separate from the body, shown in Figure 14. The fins will be secured by epoxy onto the motor mount in between the two centering rings. This motor mount section will then be able to be inserted into the bottom of the main body section through slits have were individually cut for the fins. Since each fin will be 0.125 inches the slits will only be slightly larger to allow the fins to be inserted. The mount will be secured with epoxy to the body tube.



Figure 14. Motor Retention System

3.2.1.4 Section Securement

Couplers were fabricated from 4 inch inner diameter PVC pipe couplers, shown in Figure 15. The pieces were turned on a lathe and reduced in outer diameter until a custom fit was reached for each composite tube. G10 Epoxy Glass bulkheads, with installed 1 inch eye bolts, were secured inside each coupler using composite epoxy. Couplers were then installed in the appropriate composite tubes using composite epoxy.

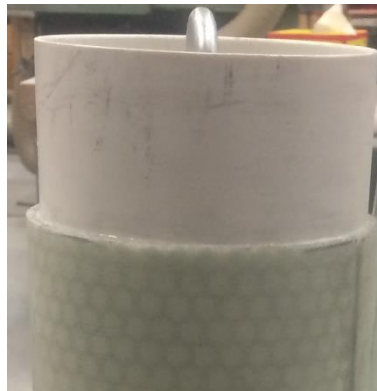


Figure 15. PVC Couplers (Installed)

3.2.2 Electrical Elements

The only electrical systems in the rocket are the avionics and payload sections. The electrical systems for the systems will be discussed in their respective sections.

3.2.3 Assembly

The rocket consists of five sections; the motor section, main avionics, main parachutes, payload, and nose cone. The main avionics section has a coupler secured on both ends so that it assembles into the motor section and connects to the main parachute section. The payload section also has two couplers on it so that it connects into the main parachute section and then will hold the nose cone.

3.2.4 Full-scale Testing

Navy Rockets completed full scale testing of the rocket on 07 Mar 15. The rocket launching can be seen in Figure 16. This launch did not include the AGSE system or the payload securement system. To account for the mass of the payload securement a mass simulator was secured into the payload section of the rocket. This mass allowed the rocket to equal the weight of the full scale rocket. At this weight and flying on the full scale motor, Cesaroni K1200, the rocket was predicted to reach 3054 feet and reached 3023 feet. The avionics were able to deploy the black powder charges and open the parachutes. The recovery system brought the rocket back down to Earth with a gentle landing. The GPS system was verified with the launch and sections were only five feet away from what the system outputted their location.



Figure 16. Full Scale Rocket during Launch.

After the recovery, the structural integrity of the rocket was inspected and only one small instance of damage occurred to the rocket. On the bottom coupler of the jettisoned payload section a small crack was developed. By inspection it was due to the carabineer hitting the side of the coupler on ejection. Navy Rockets does not feel that this damage was very critical because the coupler still worked properly in connecting to the next section. To fix this problem however, a thick PVC pipe was lathed down in order to fit the inner diameter of the coupler and was then epoxied into place thus greatly increasing the thickness of the coupler.

A change after the full scale launch is that the altimeters will be set to go off at different locations. During the full scale launch the altimeters were set to both go off at apogee which caused a large explosion of black powder. The new way is to have the altimeters deploy at apogee and then three seconds after apogee to ensure that the redundant system is effective for the flight.

3.2.5 Workmanship

Precision measurement and manufacturing techniques were used to properly construct the rocket. Attention to detail and team supervision was used to ensure each part is correctly manufactured in the same way. It was a team effort to build and assemble the rocket properly for launch.

3.2.6 Safety and Failure Analysis

The failure modes for the launch vehicle are presented below in Table 3.

Table 3. Launch Vehicle Failure Modes

<i>Failure Mode</i>	<i>Cause</i>	<i>Likelihood</i>	<i>Severity</i>	<i>Mitigation</i>
Frame Breaks	Defect in the tube from the building process	Low	High	Material Testing
Rocket Overweight	Additional components or extra epoxy in the rocket	Medium	Medium	Testing, Analysis
Catastrophic Motor Failure	The motor has a defect in which it explodes on the launch pad	Very Low	High	Research

All of these failure risks in the launch vehicle will be mitigated and tested to ensure safety for the rocket, the system, and the bystanders.

3.2.7 Mass Statement

The mass for the rocket design can be found in Table 4. Completed sections were weighed individually as well as the additional components that are used in the rocket.

Table 4. Component Masses

Section	Item	Quantity	Weight (lb)	Total Weight (lb)
Structure				
	Fiberglass Nosecone	1	0.925	0.925
	Fiberglass Payload Section	1	2.095	2.095
	Parachute Section	1	1.085	1.085
	Main Avonics Section	1	2.390	2.390
	Motor Mount and Section	1	5.095	5.095
	Launch lugs	2	0.200	0.400
Avionics				
	TT15 Dog Device	2	0.455	0.910
	Avonics Board	1	0.725	0.725
	Black Powder Charges	4	0.025	0.100
Recovery				
	Drogue Chute (24 inch)	1	0.135	0.135
	Main Chute (72 inch)	1	0.790	0.790
	Main Chute (60 inch)	1	0.620	0.620
	Shock Cord and Carbiners	3	0.350	1.050
Payload				
	Hitec HS-422 Servo Motor	1	0.100	0.100
	Arduino Micro Microcontroller	1	0.030	0.030
	12V Battery	1	1.000	1.000
	1/4" Threaded Steel Rod	1	0.286	0.286
	MaxStream xBee-Pro 900HP Wireless Serial Modem	1	0.070	0.070
	Accuride 3832C Full Extension Slide 8"	1	1.500	1.500
	11.935" Aluminium Beam	1	0.094	0.094
	32P Beam Gear Rack	1	0.028	0.028
	Beam Bracket S, Pair	1	0.009	0.009
	Beam Attachment Block B	1	0.009	0.009
	1.50" Aluminum Channel	1	0.028	0.028
	16 Tooth, 32 Pitch, 4mm Bore Pinion Gear	1	0.016	0.016
	6-32 Nylock Nuts	1	0.010	0.010
	#6 Washers	1	0.010	0.010
	Actobotics 32 RPM Precision Planetary Gearmotor	1	0.221	0.221
	Planetary Gearmotor Mount A	1	0.013	0.013
	0.625: L x 6-32 Zinc-Plated Alloy Steel Socket Head Cap Screw	1	0.020	0.020
Motor				
	Motor Tube	1	0.171	0.171
	CTI 54mm K1200	1	3.595	3.595
	54mm Motor Retainer	1	0.950	0.950
Extra				
	Miscellaneous Parts	1	0.750	0.750
	Additional Mass	1	2.500	2.500
Final Mass (lb)			27.730	

3.3 Payload Securement Subsystem

The payload section of the rocket utilizes the nosecone structure as an entry point to the payload bay. Once activated via wireless transmission, the nosecone slides away from the rocket body by a central rack and pinion system, driven by a brushed DC motor, exposing the payload bay. This bay consists of a containment area in which the payload is placed and a servomotor driven tab that will rotate over the payload to secure it inside the rocket body. This containment area is described further in section 3.9.3.

The payload section also contains an Arduino Micro control board and an xBee-Pro wireless serial modem. This wireless modem receives commands from the AGSE control element. The control board provides a link between this modem and both the brushed DC motor and the servomotor. It is programmed using the native Arduino language. There is also a 12 Volt battery power supply located in the payload section of the rocket to power all of the payload section components. All of these elements are mounted on two central support rods, made from one-quarter inch threaded steel rods, using suitable mechanical fasteners. These rods are secured to the aft bulkhead of the payload section. An eyehook is also mounted on this bulkhead, facing aft. It is used to attach the payload section and nosecone to the recovery system. Additionally, a metal slide will be mounted to both the rocket body and the nosecone. This component supports the weight of the nosecone while it is extended away from the rocket body, relieving the DC motor and its gearing from any shear forces.

During the launch process, the payload section of the rocket will initially be open, with the nosecone separated from the rocket body. Once the AGSE places the payload into the payload containment area within the payload section, the wireless serial modem will receive a command from the control element of the AGSE to rotate the payload securement tab 90 degrees, via the servomotor. Following securement of the payload sample, the brushed DC motor will activate and slide the nosecone back onto the rocket body, through the associated rack and pinion system. The nosecone will be sealed onto the rocket body with O-rings and the brushed DC motor and its rack and pinion system will lock into place. The gearing of the DC motor will prevent any back-driving of the motor, thereby providing a static force that will secure the nosecone to the rocket body. The nosecone is a protective housing for the sample during the launch procedures and flight. After the nosecone separates and lands, the payload will be able to be retrieved using the same wireless signal to open the payload section again.

3.3.1 Structural Elements

The primary structural elements of the payload section and their specifications are detailed below.

- Hitec HS-422 Servomotor
 - This servomotor operates from 4.8 to 6 Volts. At its slowest speed, it rotates 60 degrees in 0.21 seconds and produces 46 ounce-inches of torque. A servomotor was selected for this portion of the payload bay due to its simplicity of use and design. The HS-422 was selected due to its high durability and reliability in comparison to other servomotors. It remains light weight and compact while providing the necessary performance characteristics.
- Actobotics 32 RPM Precision Planetary Brushed DC Gear Motor
 - This motor operates at 12 Volts. It rotates at 32 RPM free-run and provides up to 472.1 oz.-in of torque. These component parameters satisfy the requirements of the payload section motor. This particular brushed DC motor was selected for its relatively small size and low cost in comparison to other motors.
- Pinion Gear and Gear Track
 - The pinion gear and gear track being used in the payload section are produced by Actobotics to ensure full compatibility with the DC motor system. The gear has a 4 mm bore to fit the DC motor shaft. The gear and gear track are 32 pitch with a 20 degree pressure angle.
- Accuride 3832C Full Extension Slide, 8”
 - This slide provides weight support for the nosecone while it is extended away from the rocket body. It is rated to support 75 pounds, which is more than sufficient to meet payload section requirements.
- 1/4” Threaded Steel Rods
 - Threaded steel support rods were selected for the payload bay due to the high ease of installation of the rods and the support tray for the components. These rods maintain a low weight and high strength, which makes them an excellent choice for support rods in the payload section.

The DC motor, its mounting bracket, and the associated gearing system are shown in Figure 17.

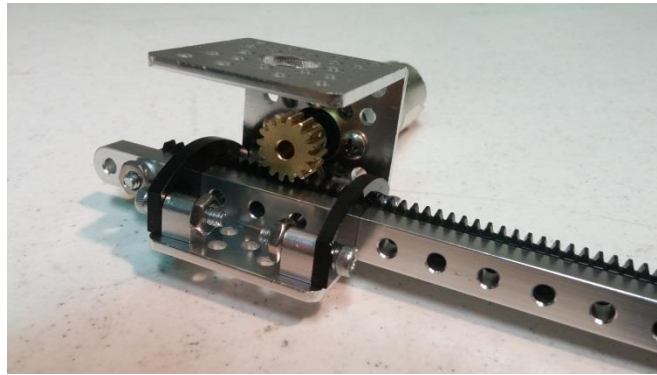


Figure 17. DC Motor and Gearing System

3.3.2 Electrical Elements

The overall electrical schematic of the payload section is shown below in Figure 18.

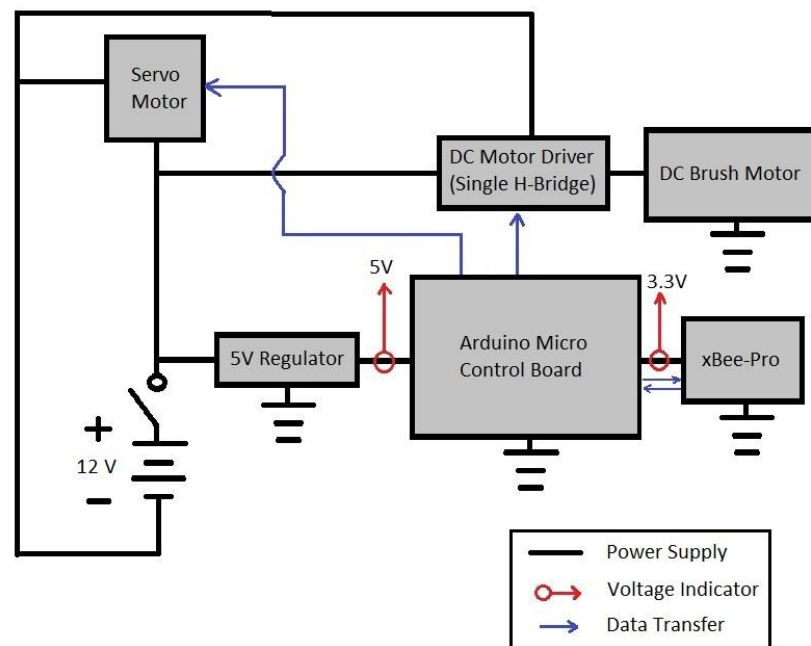


Figure 18. Payload Section Electrical Schematic

The switch shown in the above diagram will either supply or deny power to the entire payload section when turned on or off, respectively. It will be placed in an easily accessible location

within the payload section to allow for great ease of use. The primary electrical elements of the payload section and their specifications are detailed below.

- MaxStream xBee-Pro Wireless Serial Modem 900HP
 - This wireless serial modem was chosen for its simplicity, low cost, and small size. Each of these characteristics is important to the design of the payload bay. This particular modem provides the best mix of these characteristics when compared to other similar products. A wireless product was necessary for the payload bay because it eliminates the logistical issue of having a wire run from inside the rocket to an external point. That arrangement could cause issues during erection and launch, so the wireless modem was selected.
- 12 Volt Battery Power Source
 - This battery configuration will be able to provide power to all of the electrical components of the payload section of the rocket. This particular power source was selected due to its weight, cost, availability and meeting of the minimum performance characteristics required for the payload bay.
- Arduino Micro Control Board
 - This microcontroller operates at 5 Volts. It has 20 digital input/output pins, as well as a 3.3 Volt power output, which is compatible with the xBee-Pro. The Arduino control board was selected for its small size, low cost, user-friendliness, and compatibility with other components. It is shown below in Figure 19.

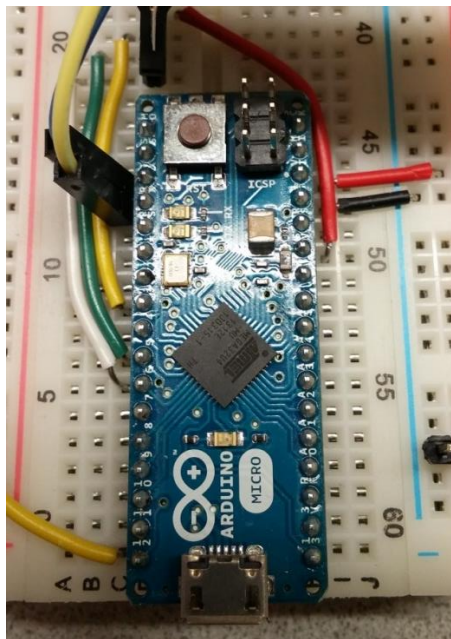


Figure 19. Arduino Micro in Testing Configuration

3.3.3 Assembly

Once the body tube and nosecone were completely constructed, assembly of the payload section began. First, the two aluminum support rods were mounted through the aft bulkhead of the payload section. Next, all of the components, except for the gear track and support slide, were mounted to a fiberglass board which was subsequently mounted to the aluminum support rods; both of these were done using mechanical fasteners and epoxy. Finally the gear track was mounted to the nosecone and run through the gear in the payload section; additionally, the support slide was mounted to the interior of both the nosecone and the payload section tube. These attachments were also done with mechanical fasteners and epoxy.

Following assembly of the finalized payload section, an inspection was done to ensure proper assembly and mounting of all components before testing began on the actual full-scale launch vehicle payload section.

3.3.4 Component Testing

As each component of the payload section was acquired, it was tested to ensure that it met both manufacturer specifications and payload section requirements. Once each component was individually verified, it was integrated into the full-scale payload section mock-up for testing. The mock payload section utilizes tubes made of the same fiberglass as the actual launch vehicle. A full second set of payload section components is mounted in these tubes in flight configuration. An external xBee-Pro wireless transmitter sends a signal to the mock-up's xBee-Pro to begin test iteration. The servomotor then rotates the securement tab over the payload, and the brushed DC motor retracts the nosecone and seals it to the body of the launch vehicle. This test was deemed a success when 23 of 25 consecutive iterations were successful. Once this test was complete, the second set of payload section components was mounted in the actual launch vehicle payload section.

3.3.5 Safety and Failure Analysis

The failure modes for the payload section of the rocket are presented below in Table 5.

Table 5. Payload Section Failure Analysis

<i>Failure Mode</i>	<i>Cause</i>	<i>Likelihood</i>	<i>Severity</i>	<i>Mitigation</i>
Payload not secured	Servomotor malfunction	Low	Low	Testing
Payload section fails to close	DC motor malfunction	Low	High	Testing
	Mechanical fault	Low	High	Testing

All of these failure risks in the payload section are being mitigated and addressed through extensive testing of both individual components and the system as a whole.

The main safety risk involved with the payload section of the rocket is failure to close the payload section. This failure would result in an improperly sealed or seated nosecone. This could greatly affect the aerodynamics or structural integrity of the rocket as a whole, which could result in erratic and dangerous flight of the rocket. This main safety risk is a result of the second failure mode presented in the above table, and as such, it will be mitigated through extensive testing of the payload section using both mock-ups and the full-scale rocket body.

3.4 Recovery Subsystem

The Navy Rockets Launch Vehicle will use a robust and well-tested dual deployment recovery system. The first recovery event will take place at 3000 feet AGL, deploying a drogue parachute to slow recovery. Then at 1000 feet AGL a second recovery event occurs deploying both the main and payload parachutes as well as jettisoning the payload section. The full recovery harness is attached to the launch vehicle body at four separate structural bulkheads, two for the drogue and one for both the main and payload parachutes.

3.4.1 Structural Elements

The bulkheads are made of G10 Fiber Epoxy Laminate, a material that was easier to cut the bulkheads from than carbon fiber without losing any strength or stiffness. Three of the four bulkheads are mounted within the sectional PVC couplers as seen in Figure 15. Each coupler has a significant lip built within the inner waist. It is against this lip that the bulkheads are mounted, opposite the direction of parachute deployment and secured by epoxy. This mounting technique allows a secondary normal force to act upon the bulkheads once the parachutes are deployed, thus increasing the robustness of the connection point.

The aft attachment point for the drogue chute differs, however, due to its location. The attachment bulkhead is the forward motor mount centering ring mounted to the inside of the body tube as well as the motor tube via the same epoxy. This can be better seen below in Figure 20. It is important to note that the figure depicts molded eye bolts. Navy Rockets employed open eye bolts that were sealed shut with epoxy.

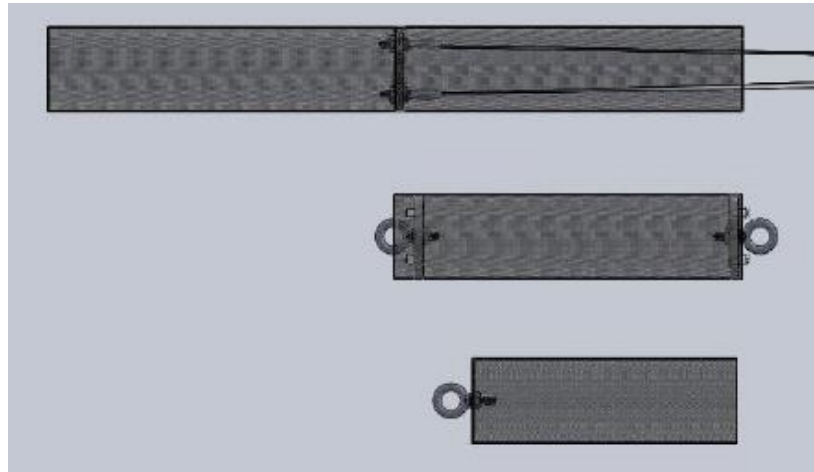


Figure 20. Recovery Harness Attachment Points

Figure 20 shows the four attachment points, without the internal components of each section. It is important to note that the eyebolts were modeled as closed designs, as the open bolts used in the REPTAR system will be epoxied shut.

Through each of the bulkheads are 316 stainless steel eyebolts that serve as the main interface between the recovery harness and the launch vehicle body. The eyebolts dedicated to the forward drogue, main parachute, and payload harnesses are single 5/16 inch eyebolts. The aft drogue harness utilizes two- 1/4 inch eyebolts mounted on either side of the motor tube as seen below in Figure 21. The hardware used on each of the five eyebolts is stacked as follows: hex nut, lock washer, flat washer, bulkhead, flat washer, lock nut. This hardware was used both to ensure a secure fit through the bulkhead as well as distribute any forces incurred during recovery across the entire bulkhead to avoid a singular point of failure. All hardware was then coated in a coat of epoxy as an extra safety precaution to mitigate the risk of the nuts backing out. The eyebolt was also epoxied shut again as an added measure to ensure that the eye would not open during recovery.

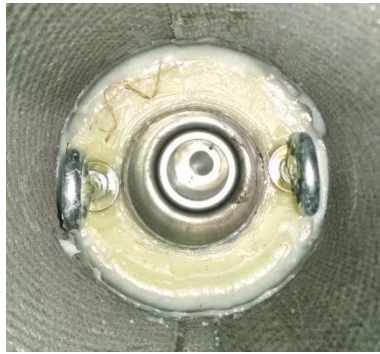


Figure 21. Droque Attachments in Motor Tube

The harness itself consists of 9/16 inch tubular nylon with loops tied in either end as attachment point. The drogue harness measures 8 feet forward and 10 feet aft. The aft drogue harness however is a 20 foot length that is doubled back to the two eyebolts mounted in the motor centering ring. This configuration was used to ensure that the deployment force was better distributed across the entire motor mount instead of a single off-center point. The main recovery harness measures 15 feet and the payload harness measures 12 feet. Each length of tubular nylon is attached to both the eyebolt and its associated parachute shroud swivel via a Black Diamond Positron screw gate carabineer depicted in Figure 22. Each carabineer is rated for 1800 lbf, and as proved during the full scale launch, can withstand any deceleration forces experienced during recovery.



Figure 22. Black Diamond Positron Screw gate Carabineer

3.4.2 Parachute Characteristics

At lift-off, the launch vehicle weighs 27.7 lbs., which translates to 24.8 lbs. at motor burnout. After jettison, the payload section weighs 15.34 lbs. and the main body weighs 10.75 lbs. The parachutes were chosen to withstand these weights and maintain appropriate rates of descent to meet the prescribed kinetic energy requirements as is discussed in Section 3.6.5. The drogue parachute used is a 24 inch diameter elliptical rip stop nylon parachute that will slow the rocket

down to an optimal descent rate 48.23 ft. /sec from 3000 feet AGL to 1000 feet AGL. The main and payload parachutes are torroidal shapes with diameters of 72 inches and 60 inches respectively. The toroid shape was chosen for its high drag (drag coefficient = 2.4) while maintaining a low packing volume and weight. These rip stop nylon parachutes will slow the main body and payload sections down to 14.45 ft. /sec and 14.58 ft. /s respectively, which projects them to land well within the prescribed 75 ft.-lbf limit. Calculations for the sizing and descent speeds are further discussed in Section 3.6.5.

3.4.3 Electrical Elements

The recovery system will utilize two identical flight altimeters to operate the launch vehicle's recovery system. The PerfectFlite Stratollogger SL100 is flight heritage hardware with Navy Rockets and continues to produce accurate, expected results. The REPTAR system will use two for redundancy of the ejection events. A full schematic of the recovery electronics can be seen in Figure 23.

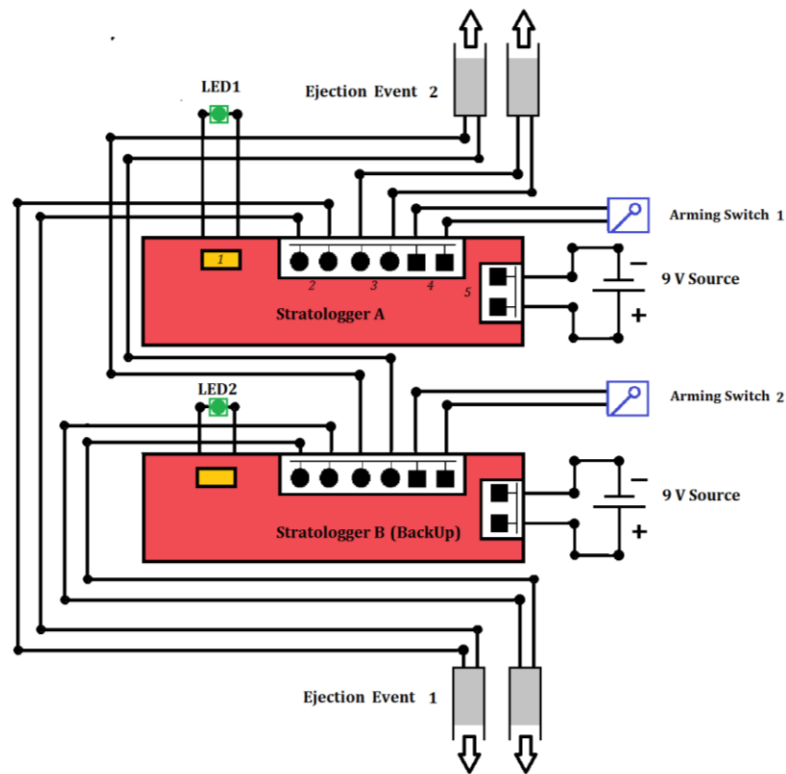


Figure 23. Recovery Electronics Schematic

The SL100 offers 10 total terminals to be used for various applications. The launch vehicle uses 9 of the 10 for both altimeters. Two of the terminals (terminal 5) are dedicated to the 9 volt power source. Two more (terminal 4) are dedicated to an arming switch that runs in series

between the ejection event terminals and the power source. These dedicated arming switches provide through-the-wall capability to power and arm the recovery system. Terminal pairs 2 and 3 are the dedicated ejection event terminals. Terminal pair 2 powers Ejection Event 1 at the default apogee setting and terminal pair 3 initiates Ejection Event 2 at the programmed height of 1000 feet AGL. Stratollogger B is programmed at staggered altitudes to provide a redundant system in the event that Stratollogger A fails to properly separate the appropriate sections. Stratollogger B's altitudes are programmed for Apogee + 3 sec. for Event 1 and 900 feet AGL for event 2. Terminal 1 is used to supply battery voltage readings to either a "beeper" amplifier or an LED. The REPTAR launch vehicle will use the terminal to light two through-the-wall LED's as a confirmation that power has indeed been supplied to both Stratologgers.

The ejection charges used will be PVC tubes that have been secured to the bulkheads around the avionics section as shown in Figure 24. This design allows for the black powder to be poured into the tubes and then covered by metal tape in order for quick and safe reuse of the charges.



Figure 24. Ejection Canisters on Avionics Section

This, however, will be more than enough capacity. To determine a rough estimate on the amount of black powder needed Equation 1 can be used.

$$\text{Black Powder (g)} = 0.006 * D_{\text{Compartment}}(\text{in}) * L_{\text{Compartment}}(\text{in})$$

Equation 1

Using this equation, the compartment parameters in Table 8, and a margin of error of 150% to slightly overestimate the pressurization force, the amount of black powder for each charge is calculated as 1.575 grams (1.50 rounded) and 0.99 grams (0.50 rounded). This amount of black powder is the baseline test to ensure that the nylon shear pins that hold the sections together are sheared and the sections fully separate. However after testing the full scale recovery system it was found that to ensure full separation of the sections, these amounts needed to be doubled.

Table 6. Black Powder Charge Calculations

	A (Drogue)	B (Main)
DCompartment (in)	5.0	5.0
LCompartment (in)	35.0	22.0
Calculated Amount (g)	1.575	0.99
Experimental Amount (g)	3.0	2.0

To prevent any damage to the parachutes from the ejection charge 2- 18 inch Nomex fire resistant protective barriers will be utilized. One will be placed along the harness in the drogue assembly, while the other will be placed along the harness in the main parachute assembly. Also each ejection charge will be topped with a different colored powder paint to identify which charge pressurized during deployment.

3.4.4 Recovery Schematic

The two recovery configurations following the two ejection events can be seen in Figure 25. Note: All components are to scale with exception of the recovery harness lengths, which were shortened in Solid Works to provide productive figures. Also shoulders between sections and the nylon shear pins are not displayed.



Figure 25. The Launch Vehicle in Recovery Configurations after Ejection Event 1 (left) and Ejection Event 2 (right)

3.4.5 GPS Transmitters

The TT15 Dog tracking device from Garmin is used to track both sections of the rocket during and after launch. Each section will contain a tracking device that transmits back to a hand held receiver. The GPS is capable of being detected for up to seven miles while using the MURS frequency. The characteristics of the GPS can be found in Table 7.

Table 7. GPS Characteristics**

VHF Radio Specifications

MURS (Multiuse Radio Service) frequency	151.82 MHz
	151.88 MHz
	151.94 MHz
	154.57 MHz
	154.60 MHz
VHF range	Up to 7 miles (11.2 km) - line of sight
DC 40 output power	2 watts

**Astro 320 User's Manual

3.4.6 Recovery Testing

Ground testing of a subscale recovery system was completed in order to ground test the deployment of parachutes. The parachutes were packed and flame retardant wadding into a ½ scale rocket fuselage section. The fuselage section was inserted into a small section of PVC pipe which has been glued to a section of plywood. Through a hole in the bottom of the plywood, a black powder loaded ejection canister was inserted. The ejection charge was detonated using a standard model rocketry launch trigger switch. The system was modeled after the recovery deployment system of previous rockets and shown in Figure 26.

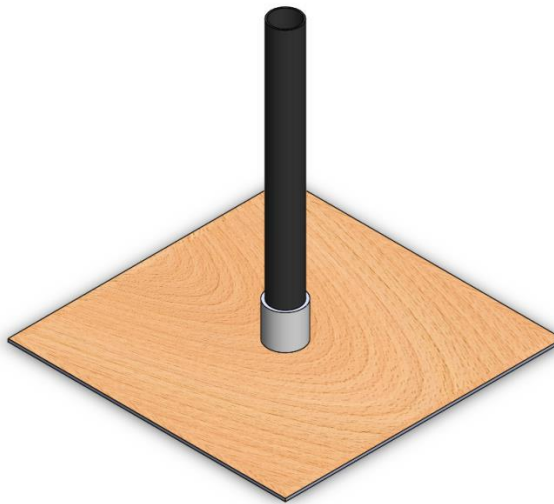


Figure 26. Recovery Test Stand

3.4.7 Safety and Failure Analysis

The recovery system has been designed such that in the event of an avionics failure, there are back-up systems and wiring in place to continue operability and complete the mission successfully. The dual arming switches, the black powder charges, and the avionics themselves are fully redundant.

With regards to the recovery hardware, each item has been carefully selected for either its flight heritage (in the case of the ejection canisters and altimeters) or has a significant margin of error in its rated strengths. The 5/16 inch Type 316 Stainless Steel eyebolts are rated for a 1000 pound working load, and the tubular nylon harness is rated for 1500 pounds of tensile force. Each eyebolt was epoxied shut to increase its working load and will be epoxied in place with its backing nut and a locking washer to ensure neither back out. The main and payload parachutes will be supporting close to half their maximum loads of 28 and 19 pounds respectively.

With regards to safety, the single item that needs mention is the black powder charge. The canisters will be loaded last as a safety precaution, and the master switch prevents any accidental discharge before continuity. When the black powder is finally loaded, all other team members will be at safe distance and all safety precautions will be met.

3.5 Propulsion

3.5.1 Final Rocket Motor Selection

The selection of the motor was dominated by three principle factors: impulse, diameter, and apogee. The length and impulse of the motor were first looked at. As long as the total impulse was kept under the required 5120 N-s, or a maximum of an L-class motor, any motor could be used. The second constraint of motor diameter was then put into Open Rocket, rocket simulation software. For our design, a motor diameter of 2.13 inches was chosen. This narrowed the choices to mostly K motors and a few L motors. Finally, the motor was chosen based on the required apogee of 3,000 feet with a buffer zone of 100 feet. This led to the selection of a K1200WT motor by Cesaroni Technology Inc. There were other motors that came within 15% of the targeted 3100 foot goal notably the 2130-K600-WH and the K750-17 motors. Figures 27-29 below are graphs, generated from Open Rocket, depicting vertical motion vs. time in the K600, K750, and K1200 motors respectively.

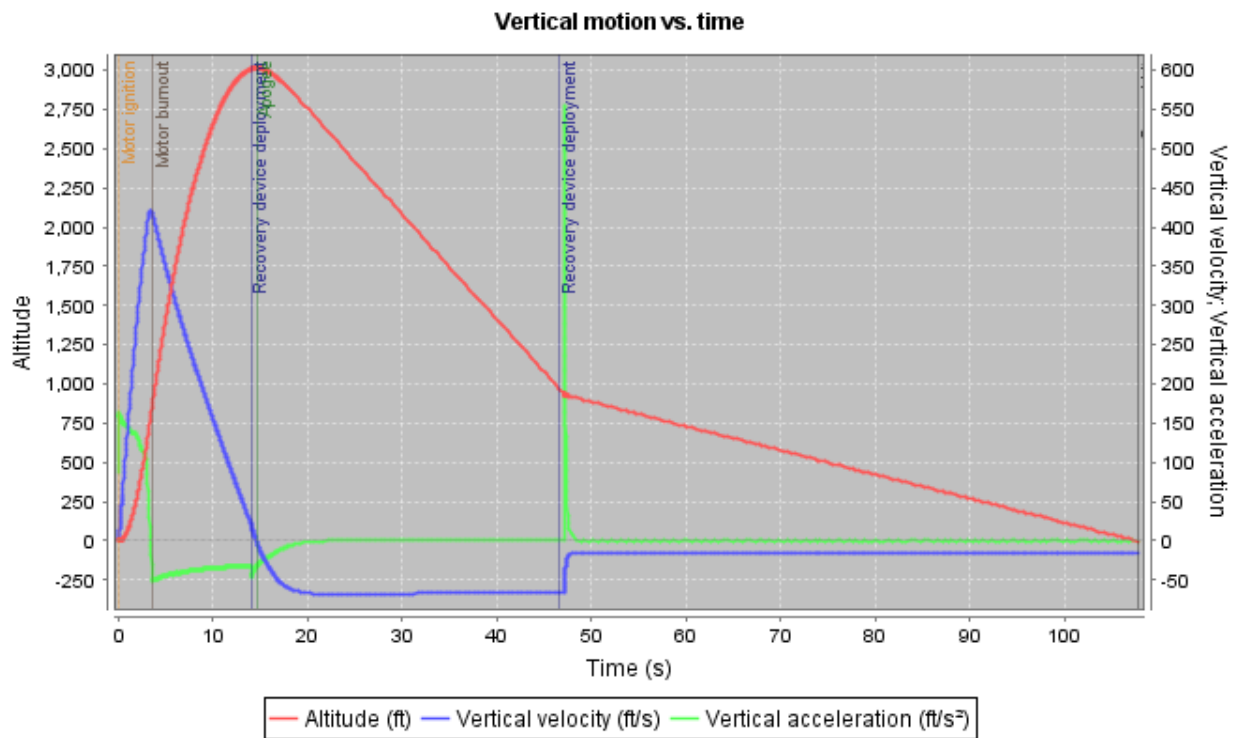


Figure 27. K600 Vertical Motion vs. Time

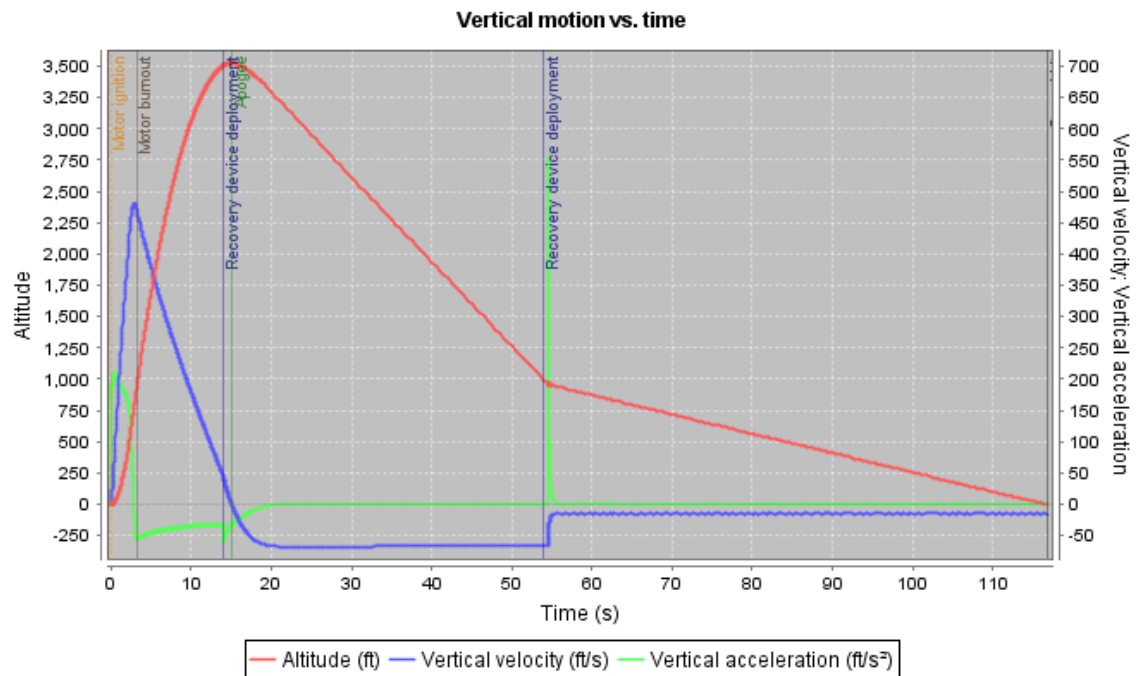


Figure 28. K750 Vertical Motion vs. Time

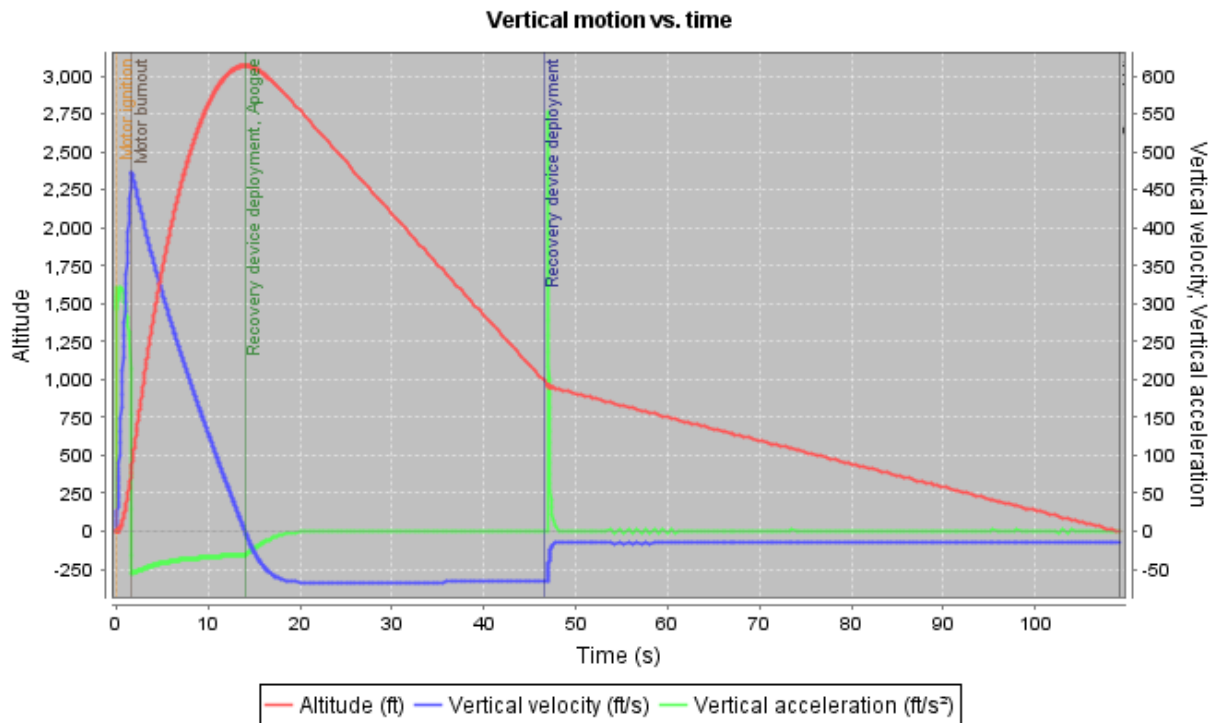


Figure 29. K1200 Vertical Motion vs. Time

The K600 motor reaches 2,997 feet, 3 feet below the required altitude of 3,000 feet. However, the desired margin of error of 100 feet makes choosing this motor too risky, based on unforeseen weight and drag that will occur on the day of the launch. The second motor, K750-17, reached 3,534 feet in the simulation. This is above the desired altitude of 3,100 feet by 434 feet. This would be too great of a deduction to the final grade to justify having that much excess height in order to guarantee reaching 3,000 feet on launch day. It would also be a safety risk and exceed the altitude requirement. The last motor, the K1200WT-16, was chosen because it reached close to the desired height with an apogee of 3,068 feet, only 32 feet under the desired altitude of 3,100 feet. It also has a given total impulse of 2011 N-s.

After selecting the K1200 motor based on altitude calculations, competition thrust requirements were considered. Using Figure 30 below, a maximum thrust of approximately 1,350 N was determined. This value will be essential in developing a motor mount to sustain this force. Due to the predicted performance of the K1200 motor, it will be used in the final rocket design.

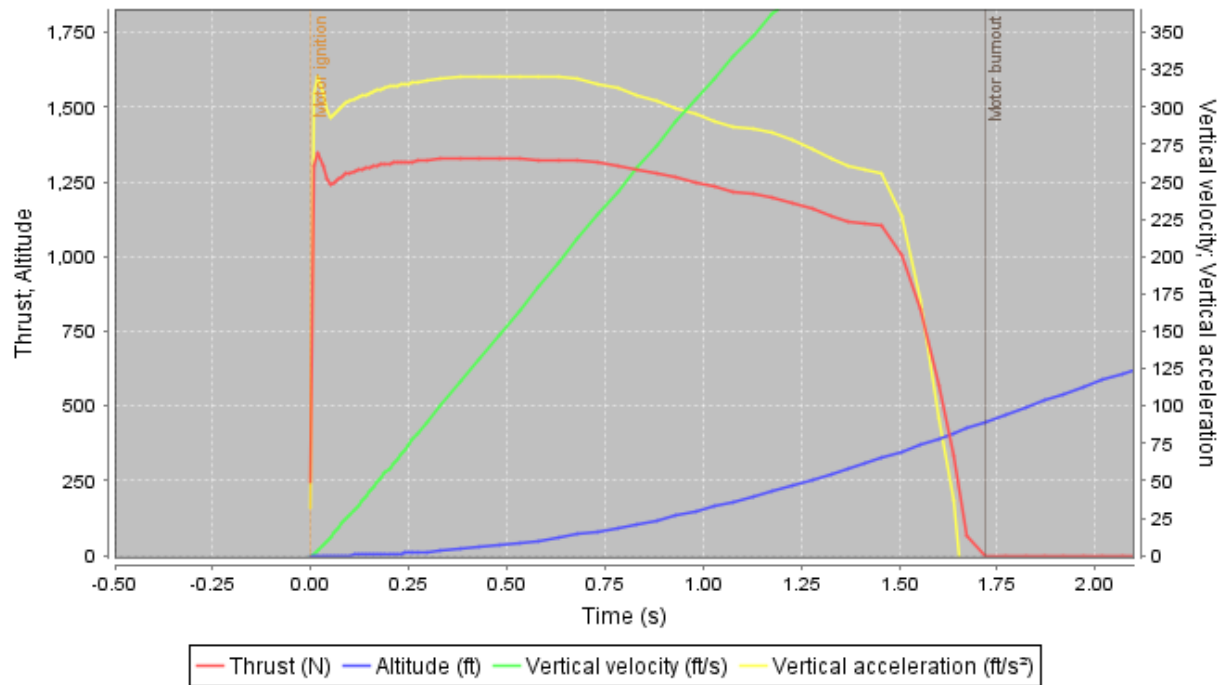


Figure 30. K1200 Thrust and Vertical Motion vs. Time

3.5.2 Motor Mount Design

The motor mount was designed using carbon fiber and fiber glass laminate. A carbon fiber tube of 2.12 inches in diameter was cut to a length of 25 inches to accommodate for the length of the motor, 3 centering rings, and 2 harnesses for the recovery system. During launch operations, the motor casing with the motor in it will be able to be removed and inserted to the motor mount during the preparation process on launch day. On the aft-most centering ring is the retention system for the motor, which consist of a metal ring that was screwed into the centering ring itself with a screw-on outer ring. This system will prevent the motor from moving in either the forward or aft directions. The fins are 0.125 inches thick and have an area of 47.5 square inches. The complete component sizes can be found in Appendix B. The fins were secured with epoxy directly on to the carbon fiber motor mount casing, each fin 120° apart. 3 slots, each 120° apart and approximately 0.14 inches wide, were cut into the aft section of the body to account for the width of the fins. The motor mount was then inserted into the aft section and secured on the outside of the body with epoxy.

3.5.3 Flight Reliability and Confidence

Theoretical Open Rocket altitudes were compared to empirically measured altitudes during three previous high-powered rocket launches. Empirical data varied by less than 3%, indicating that the theoretical values represent a reliable estimate of true performance. This small error gives a good expectation to the performance for the final rocket during testing and competition. Also, when the rocket is tested before the competition, it will be checked against the predicted values in order to ensure that it meets the requirements and expectations.

3.6 Mission Performance Predictions

3.6.1 Performance Criteria

In order for this year's REPTAR project to be a success, Navy Rockets will deliver an autonomous ground support element capable of loading the specified payload into a rocket, launch the rocket to 3000 feet AGL, and return both the main rocket body and the jettisoned payload section safely to the ground while meeting all specified mission criteria listed above.

3.6.2 Subscale Flight Results

Three members of Navy Rockets are high power rocketry certified, with one being a level two. One of the subscale testing rockets was used in a level two certification flight. This flight was predicted by Open Rocket to reach 2100 feet and on launch day the rocket reached 2041 feet in altitude. This gives the team an idea on how precise the Open Rocket program is compared to actual flight data. This knowledge allows the team to account for a possibly lesser altitude compared to the Open Rocket simulation.

Navy Rockets complete multiple subscale launches on 18 January 2015 at Higgs Sod Farm with MDRA. These launches were to test different aspects of the full scale launch.

The first test rocket was a one half scale rocket to the full scale rocket, shown in Figure 31. The rocket was a modified LOC Precision Hi Tech and flew on a Cesaroni Tech I242 motor. The I242 motor was used because it was as close as possible to half the thrust of the full scale motor. The rocket had mass simulators in it to equal half of the full rocket and to ballast the weight positions. The CG and CP of the test rocket followed closely that of the full scale rocket. The rocket flew to an altitude of 1124 feet which was close to the predicted 1100 feet altitude. The rocket successfully launched and recovered while fully intact.

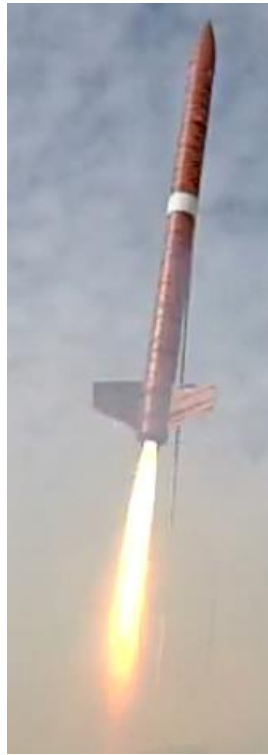


Figure 31. Half Scale Rocket Launch

The second test rocket was flown twice on launch day. It was also a modified LOC Precision Hi Tech and flew on a Cesaroni Tech I242 motor. This rocket had the GPS and dual deployment recovery system that will be incorporated into the full scale rocket. The rocket flew to 4113 feet and 4125 feet in the two launches. The purpose for such a high altitude was to determine if the avionics systems fully work on the boundaries of the launch. The systems were successful in both launches proving that the avionics plan for the full scale will work properly during and after flight.

3.6.3 Flight Simulations

Varying weather conditions will have an effect on the REPTAR launch vehicle on the day of the launch. In order to predict possible consequences of varying weather, a computer model of the launch was run through Open Rocket at wind speeds of 5, 10, 15, and 20 mph. Graphs of the results are shown below in Figures 32-35.

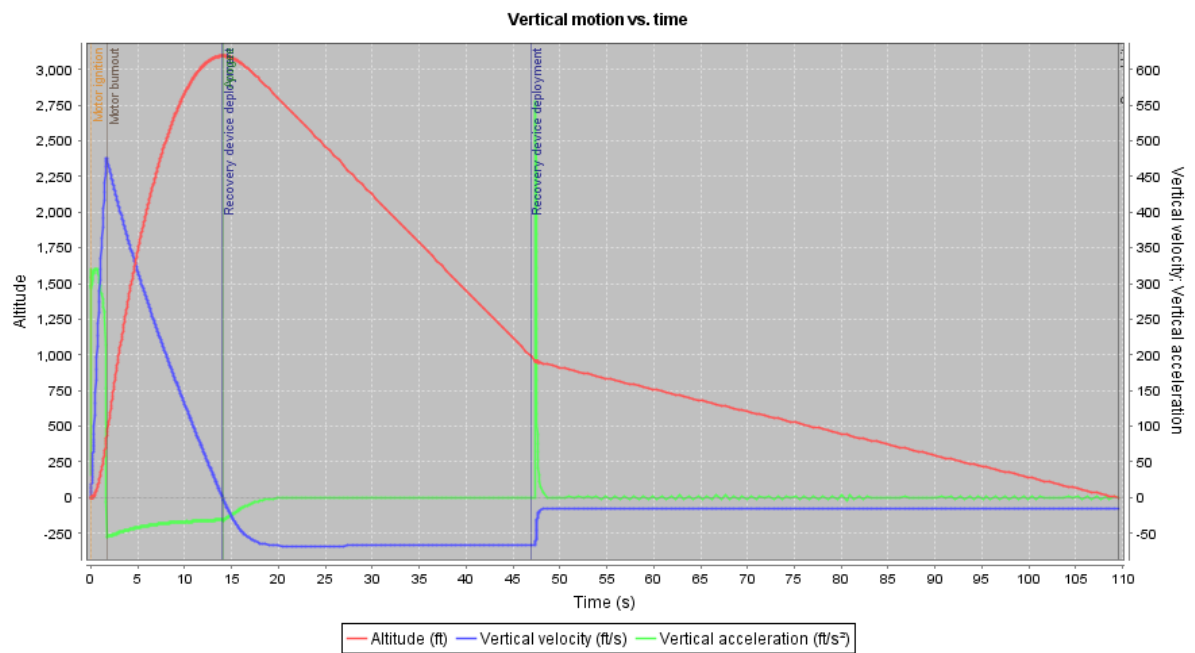


Figure 32. Vertical Motion vs. Time at 5 mph

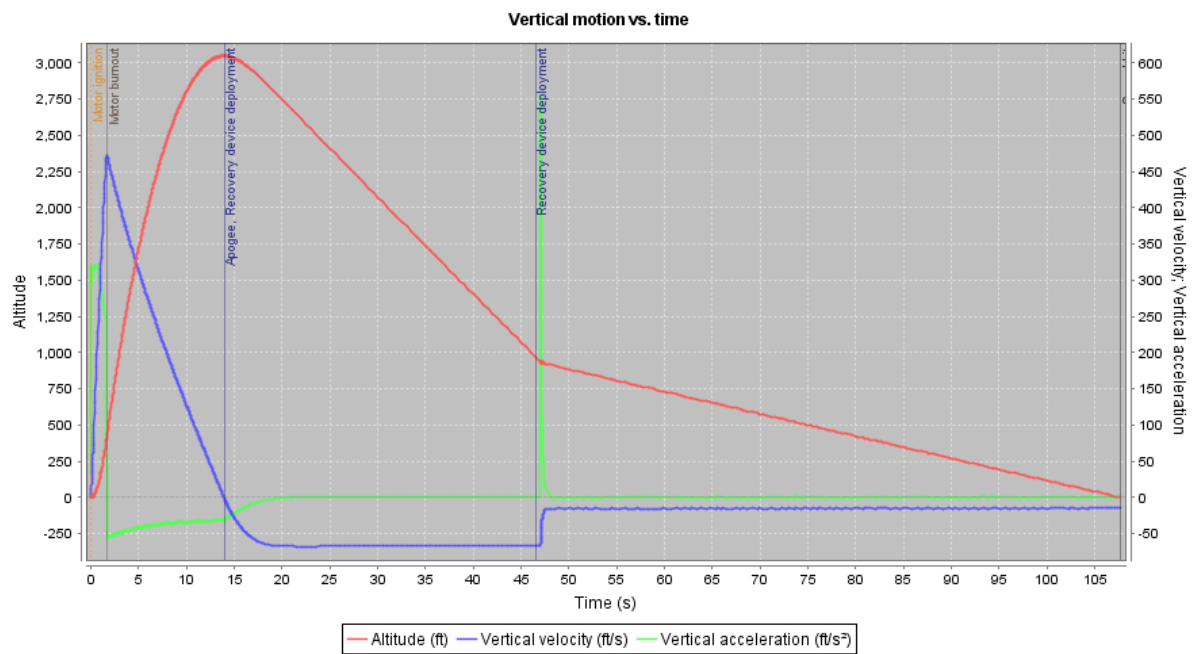


Figure 33. Vertical Motion vs. Time at 10 mph

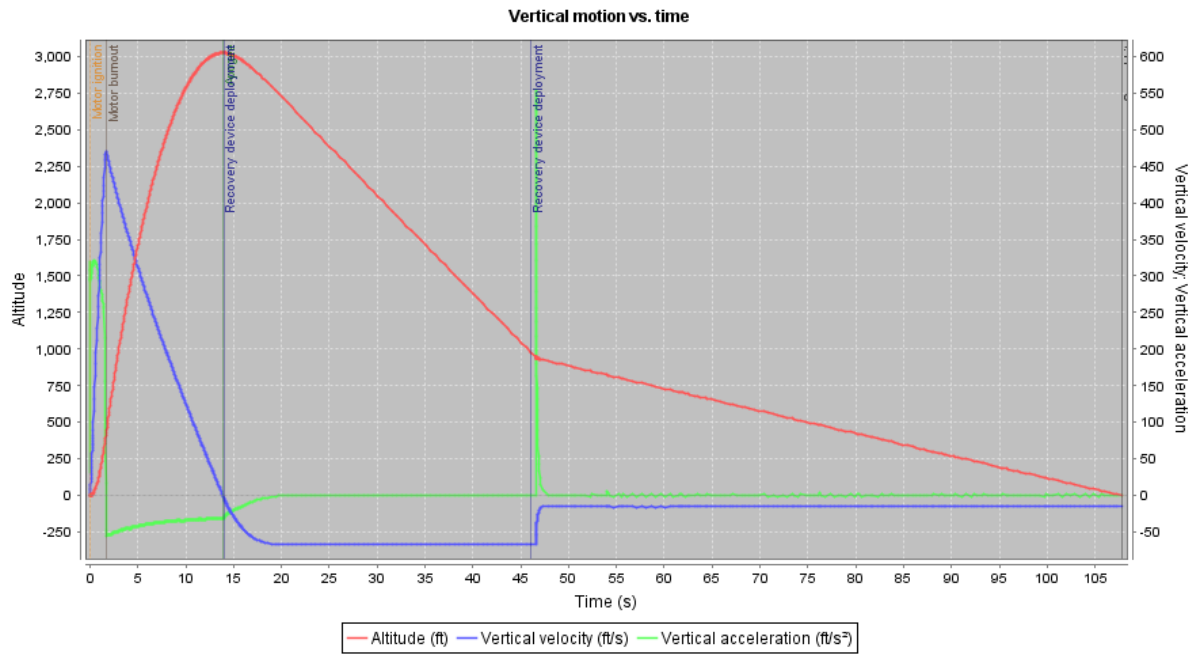


Figure 34. Vertical Motion vs. Time at 15 mph

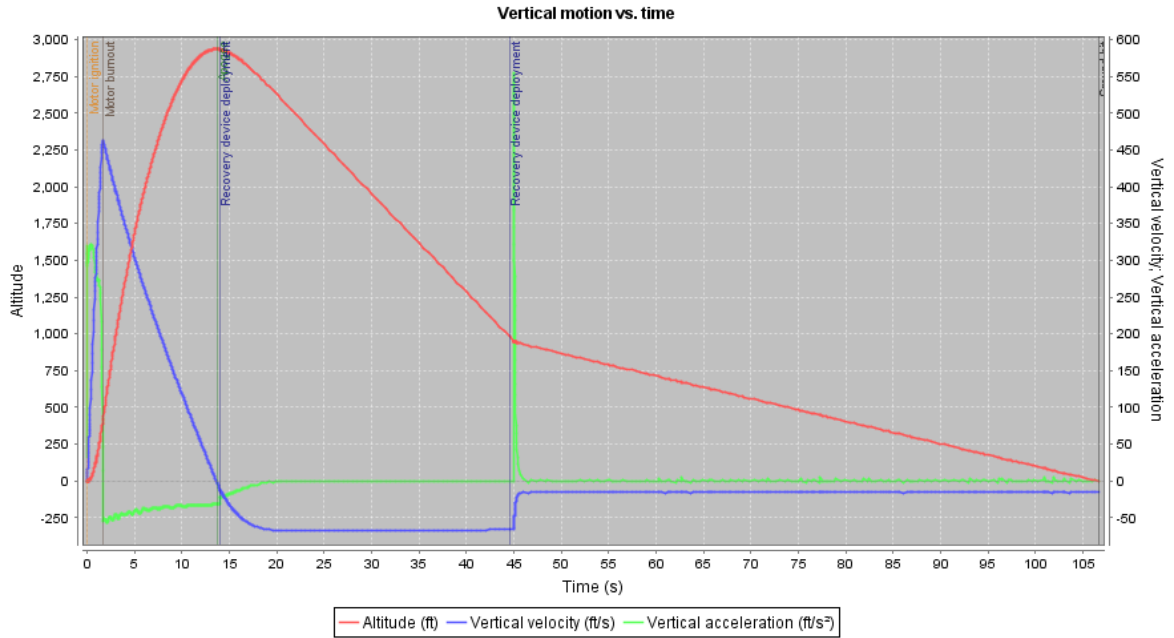


Figure 35. Vertical Motion vs. Time at 20 mph

The highest apogee occurred at 5 mph with a height of 3095 feet. The lowest apogee occurred at 20 mph with a height of 2934 feet. At 10 mph and 15 mph, the resulting apogees were 3057 and 3025 respectively. As sustained winds increase, the vertical motion of the rocket will be translated into greater horizontal motion. The Navy Rockets team will have the greatest chance of reaching the goal height of 3000 feet as long as winds do not go over 15 mph.

3.6.4 Rocket Stability

The stability of each motor as compared to angle of attack is shown in Figure 36. This figure was created using the OpenRocket program and allowed the stability margin to be determined throughout flight.

A stable flight refers to a balance of the six degrees of freedom that the rocket encounters during flight. A successful balance of a rocket's flight is when the rocket does not rotate around the pitch or the yaw axis. By rotating on these axes the flight will alter course and reduce the performance of the rocket. A rocket that has the Center of Gravity (CG) forward of the Center of Pressure (CP) will have a positive stability relationship. This leads to a rocket being able to fly straight in the direction of the launch rail and have pitch stiffness to deter from external forces attempting to change the course of the flight. Using open rocket, the CG and CP were calculated to be 56.8 inches and 80.1 inches from the nose cone respectively during flight.

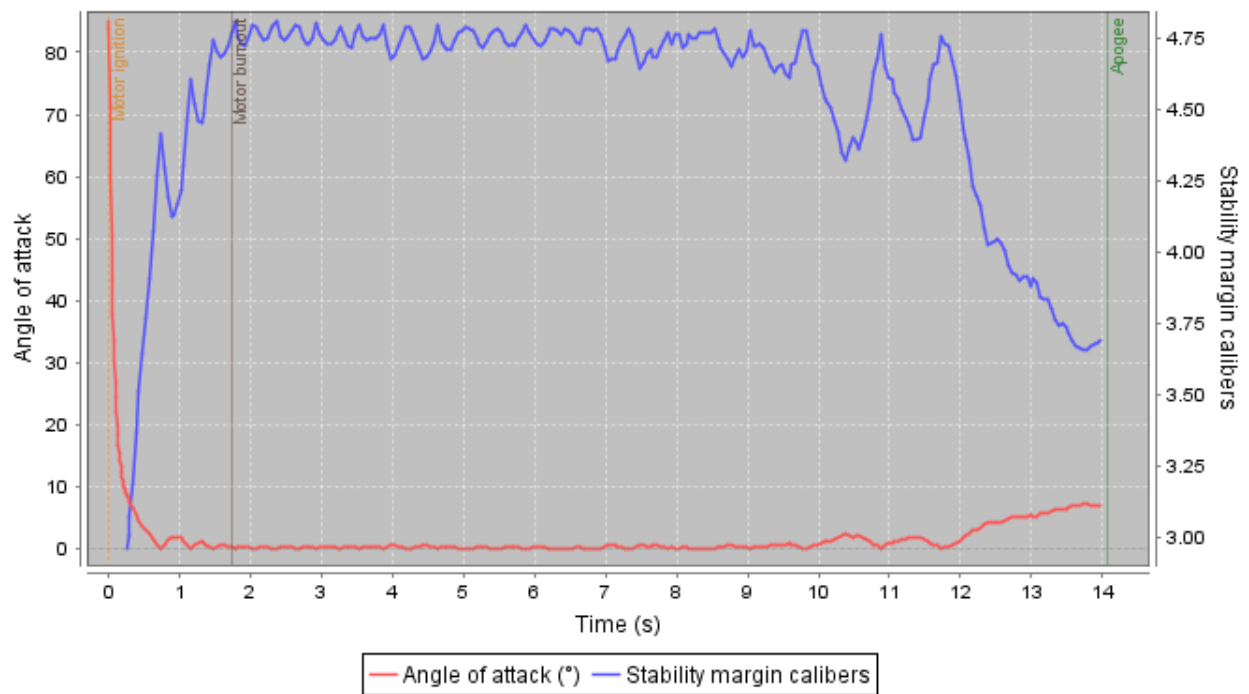


Figure 36. K1200 Stability Margin and Angle of Attack vs. Time

This plot helps predict the flight path of the rocket during testing, which will lead to modifications and a change in motors if necessary. Stability margin is measured in calibers, and is defined as the ratio of the distance between the CG to CP and the diameter of the rocket. Typically stability margin should be kept between one to two calibers from the original margin. The main rocket the margin was an average of 4.15. This is high, but the possible instabilities here are not nearly as worrisome as a stability margin below one caliber. A stability margin of around 4 is typical in high power rocketry and additional simulations and flight observations proved the rocket would not be affected. The high stability margin makes the rocket overly stable and results in a reduced chance of flight alternation from any external forces. The overly stability of the rocket is not great enough to alter the flight path during the possible flight conditions. The stability margin is high during the flight and the rocket will become less overly stable as it reaches apogee as the CG and CP move closer together. This less overly stable flight will result in a continued successful balance of the degrees of freedom and an efficient rocket flight.

3.6.5 Kinetic Energy

The final kinetic energy of the sections was determined using several calculations beginning with the masses of the sections at different point in the flight. The masses are listed below in Table 8.

Table 8. Mass of Sections During Flight

Sections	Total Weights (lbf)
Pre-Launch	27.70
Post Burnout	25.51
Payload	10.73
Main Body	14.78

The next step is finding the velocity of the section as it comes down. By rearranging the equation to find the parachute surface area, the terminal velocity (V) can be found for once the parachute is fully deployed using Equation 2, where S is the effective drag area of the chute, C_d is the coefficient of drag, ρ is the air density (.averaged to be 0.00200 slug/ft³), and W is the weight of the rocket in lbs.

$$V^2 = \frac{2(W)}{S(C_d)(\rho)}$$

Equation 2

Once the final velocity was found, the kinetic energy could be calculated using Equation 3. The values can be found in Table 9.

$$KE = \frac{1}{2}(mv^2)$$

Equation 3

Table 9. Kinetic Energy Values for Sections

Vehicle Section	W (lb.)	Cd	S (ft ²)	V (ft./s)	KE (ft-lb)
Full With Droque Deployed	25.51	1.5	3.02	62.97	1884.97
Main Body	14.78	2.2	27.14	14.45	47.94
Payload	10.73	2.2	18.85	14.58	36.34

From this calculation the kinetic energy values for the two separate sections is well under the required 75ft-lb requirement.

3.6.6 Drift Analysis

Due to the large size of the Navy Rockets launch vehicle, wind has a significant impact on the recovery portion of the flight profile. According to simulation data, at no point will the wind affect the target altitude of the rocket as the 3000 foot mark is consistently met. However the lateral drift due to the wind does become as problem. When modeled using the OpenRocket and the best case scenario with regards to wind (5° launch angle oriented into the wind) the launch vehicle stays within the required 2500 feet of lateral drift in wind speeds up to 20 mph. When modeled using the worst case scenario (5° launch angle oriented with the wind) the launch vehicle crosses this 2500 foot mark at winds of roughly 13 mph. It is important to note at this point, that all drift values are unique to the main body section that is jettisoned at 1000 feet AGL. In all simulations, this section drifted farther than the payload section. The drift data at both the best and worst case scenarios at various wind speeds is seen in the Table 10 and Figure 37.

Table 10. Wind Drift Values at the Best and Worst Case Scenarios

Wind Speed (mph)	“Upwind - Best Case”		“Downwind - Worst Case”	
	Lateral Drift (ft.)	Altitude (ft.)	Lateral Drift (ft.)	Altitude (ft.)
0	644	3089	644	3054
5	83	3072	1341	3046
10	823	3052	2045	3047
15	1554	3022	2731	3037
20	2370	3009	3458	3024

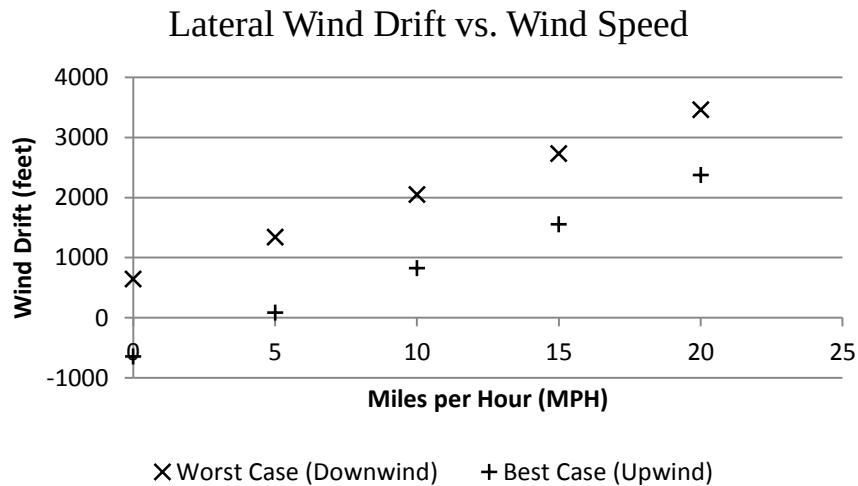


Figure 37. Lateral Wind Drift vs. Wind Speed for the Best and Worst Case Scenarios

To better understand the wind drift problem, the launch vehicle’s flight profile was modeled at 11 different wind angles through each of the wind speeds from 12 to 20 mph. This created a 3-D matrix of values that allowed the team to pinpoint the specific wind conditions that push the launch vehicle out of its drift boundaries. This data visualized as a surface plot can be seen below in Figure 38.

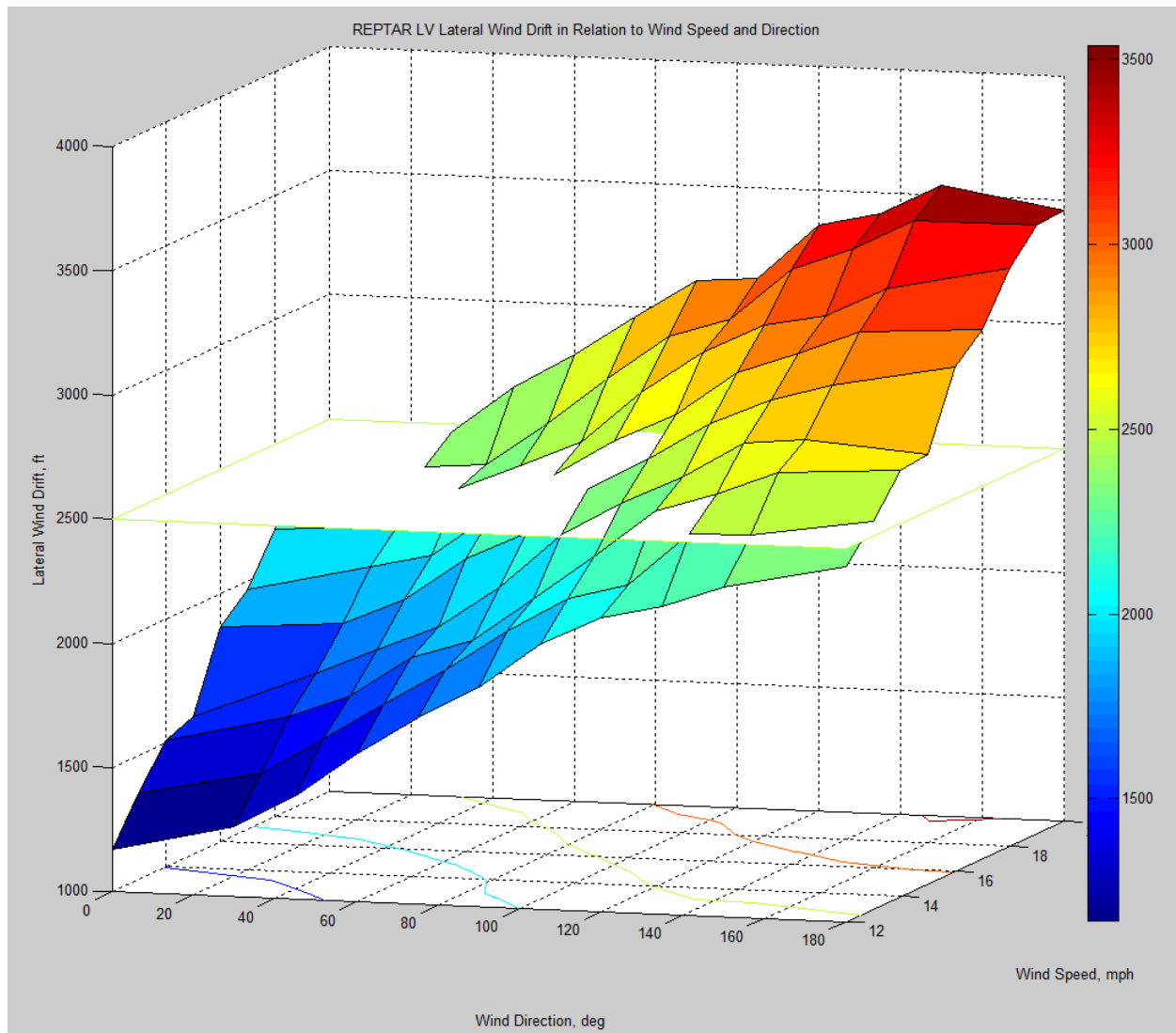


Figure 38. Surface Plot of Wind Drift with Respect to Direction and Speed

This plot allows the team to gauge the wind conditions at launch and determine whether or not to utilize the High Wind Parachute configuration to adjust the launch vehicle's flight profile. Both the 72 in. torroidal parachute on the main body section as well as the 60 in. payload parachute will be reefed in this configuration to decrease the diameter of the parachute and the effective surface area available to the air. This will decrease the coefficient of drag of the parachute significantly and allow the payload section to descend faster and remain within the 2500 foot drift mark. The new diameter parachute for the main body will become 50 in. The new descent speed will thus cause the total kinetic energy to become 67.6 ft-lbs, within the 75 ft-lb margin, while the new wind drift will become 2430 ft. as modeled in Open Rocket.

3.7 Vehicle Verification

3.7.1 Wind Tunnel Testing

In an effort to model the static and dynamic stability of the rocket during flight, a scale model of the rocket was constructed and tested on a sting balance in the open loop, open return Eiffel wind tunnel located at the United States Naval Academy. This scale model consisted of multiple different materials. The functional test plan can be found in Appendix C.

3.7.1.1 Nose Cone

The nose cone was 3D printed in order to create 10-15 pressure ports along the leading edge of the rocket. It was determined that additive printing was the only plausible way to create tunnels inside the nose cone to determine pressure. The idea was the pressure port at the leading edge, PP1, will be tunneled to a point at the bottom of the nose cone that will be inside the PVC section. This tunnel would allow the pressure to be measured at PP1 using a standard pressure measurement tool inside the body of the PVC pipe. However, the material the nose cone was printed with was porous and could not hold pressure through the tunnels.

3.7.1.2 Body Section

The body section of the test model was made of Polyvinyl chloride (PVC). The body was modeled out of PVC because of reduced cost, and simplicity of construction. PVC was determined to be sufficient because of few constraints regarding weight and material strength. The body section contains 7 pressure ports in order to calculate the pressure along the body of the rocket. Directly across the pressure ports, access holes were drilled in order to put the stainless steel tip that connected to the tygon tubing into the pressure port of the PVC. The access ports were covered by aluminum tape during the testing.

3.7.1.3 Fin Section

The fin section was also 3-D printed. The fin section was attached to the body section by means of an aluminum attachment located on the inside of the rocket. The main purpose of the aluminum attachment was to connect the rocket to the sting balance. The fin section was chosen to be 3-D printed in order to accurately attach the fins at 120° intervals. The additive printing of the whole fin section allowed for the sting attachment to be lengthened and hold the PVC in place.

3.7.1.4 Testing

The scale model was tested on the sting balance in the Eiffel Wind Tunnel at varying Reynolds numbers, and angles of attack. To determine the pressure along the nose cone and rocket body at different radial locations, the nose cone was to be manually rotated on the sting balance. Because the speed of the Eiffel Wind Tunnel limits the Reynolds number, the Reynolds numbers are characteristic of the boost phase of the actual flight of the full-scale rocket, which is where disturbances are most detrimental to stability of the rocket. The Reynolds number was limited by the maximum free-stream Reynolds number of the wind tunnel, and the overall size (namely the height and width) of the test section.

The goal of the wind tunnel testing was to model the pressure distribution along the rocket. However, because the pressure in the nose cone was unable to be transferred via the tunnels, the pressure along the rocket was not measured. Without the pressure distribution data, the only data taken from the rocket was drag data at varying Reynolds numbers and angles of attack.

Because the full-scale rocket was made out of carbon fiber, and the scale rocket was made of a plastic nose cone, PVC body section, and HDF fins, the skin-friction drag coefficient will be different. For this reason, the difference in skin friction coefficient of the scale model and the full-scale rocket was not taken into account. Therefore, the significance of the drag calculated by the sting balance was attributed to profile drag due to the geometry of the rocket and placement of the fins, and not the difference in skin-friction drag due to the material of the rocket.

3.7.1.5 Results

The original goal of measuring the pressure distribution was to prove the center of pressure found by OpenRocket. However, without this data, only the coefficient of drag, C_D , was proven by means of the wind tunnel testing. The data showed that the mean and median C_D of the rocket design was both 0.51. As shown in Table 11, the C_D did not change significantly at varying Reynolds numbers and stayed around 0.51 the whole time.

Table 11. C_D Values from Wind Tunnel

Reynold Number (million per foot)	Average C_D
1.37	0.516
1.48	0.520
1.58	0.524
1.68	0.511
1.79	0.509
1.89	0.505
1.99	0.510
Average C_D	0.51

3.7.1.6 Analysis

The C_D of the wind tunnel scale model closely matched that of the coefficient developed on the OpenRocket software. From the C_D , the determination of the height of apogee is simple based on the trust curve of the motor and the weight, and drag of the rocket. Because the drag coefficient given by open rocket can be trusted, it can be assumed that the height of apogee determination is trustworthy as well. Further testing on the full-scale model will confirm the value given by OpenRocket software.

3.7.2 Requirement Verification

Navy Rockets have completed and verified all AGSE requirements for the project. The list of requirements and verification methods can be found in Appendix D.

3.8 Vehicle Safety

3.8.1 Safety Analysis

Some of the major safety concerns for the vehicle can be found in Table 12. These safety concerns have been considered during the planning and building process to ensure that everything works safely. These failures have been mitigated so that the rocket can launch and be recovered successfully.

Table 12. Vehicle Safety Analysis

<i>Failure Mode</i>	<i>Cause</i>	<i>Likelihood</i>	<i>Severity</i>	<i>Mitigation</i>
Parachute fails to deploy	Poor packing or damage during launch	Low	Medium	Practicing packing the parachutes and ensuring that all equipment is functional
Sections fail to separate	Improperly connected sections	Low	High	Ground testing and verification of the rocket sections
Structural failure	Defect from building process or damage from transportation	Low	High	Ensuring careful building and transportation practices
Altimeter fails to deploy parachutes	Not enough power or faulty wiring systems	Medium	High	Testing the system and using new batteries
Payload section does not close	Section jams or will not secure all the way	Medium	High	Testing and verifying that the system closes properly

3.8.2 Personnel Hazards

Safety during building and launching of the rocket is a major consideration for Navy Rockets. The team has practiced safe procedures to ensure that no one gets injured during the competition. Some of the potential concerns for the team can be found in Table 13. Navy Rockets will continue to practice safe building and launching procedures.

Table 13. Personnel Hazards

<i>Failure Mode</i>	<i>Cause</i>	<i>Likelihood</i>	<i>Severity</i>	<i>Mitigation</i>
Chemical burns	Poor handling of dangerous chemicals	Low	High	Oversight while using dangerous chemicals
Injury from Power Equipment	Poor safety practices and lack of power tool safety knowledge	Medium	Medium	Learn about equipment and work with a partner
Black Powder Misfire	Electronics armed too early or current near black powder	Medium	High	Ensure that black powder is stored properly and that excess powder is disposed of after launch
Catastrophic motor failure	Damage to motor	Low	High	Ensure proper storage and transportation for the motor
Failure to follow planned flight path	Failure to set up equipment properly	Low	Medium	Ensure safety checks and proper launch procedures are followed

3.8.3 Environmental Concerns

Navy Rockets does not have any environmental concerns that have been deemed likely to happen. The team will ensure that materials are properly disposed of so that we do not damage the environment.

3.9 AGSE Integration

3.9.1 Integration Plan

3.9.1.1 Payload to Rocket Body

The payload section of the rocket is a main compartment of the rocket body. Therefore it is critical that the payload section falls within any constraints placed on the rocket as a whole, most notably size and mass, and is co-developed with the remainder of the rocket body. The interface between the payload section and the remainder of the rocket consists of mechanical fasteners,

such as brackets or bolts, and epoxy. The payload bay components are attached to support rods, which are mounted through the aft bulkhead of the payload section. To ensure full interoperability of the payload section with the remainder of the rocket body, the payload lead is working closely with the chief engineer and the structures lead throughout the entire process of design and development.

3.9.1.2 Vehicle to Ground Interface

The payload section of the rocket body interfaces with the AGSE through the use of wireless transmissions. Within the payload bay, there is a MaxStream xBee-Pro wireless serial modem, which operates at 900 MHz. The MaxStream xBee-Pro within the payload bay interfaces with another MaxStream xBee-Pro, which will be connected to the control segment of the AGSE. This link between the two modems allows for commands to be sent from the AGSE to the payload bay and for feedback from the payload bay to be sent back to the AGSE. To ensure the flawless operation of this interface, the payload and AGSE leads are working hand-in-hand throughout the design and development stages.

3.9.2 *Element Compatibility*

All components of the payload section are fully compatible with the remainder of the rocket body. All of the components are mounted on two aluminum support rods, which are then secured through the aft bulkhead of the payload section. This creates full compatibility between the payload components and the rocket body. Any additional securement that may be needed in the payload section will be done with epoxy or mechanical fasteners, namely brackets. This will allow for a firm and secure mounting of components within the payload section, as necessary.

3.9.3 *Housing Integrity*

The housing within the launch vehicle payload section for the standardized payload sample is made of a thin fiberglass sheet, approximately 1/16 of an inch thick. This housing, shown below in Figure 39, is essentially a box without a lid, with interior dimensions of 5.25 inches by 1.5 inches by 1.5 inches.

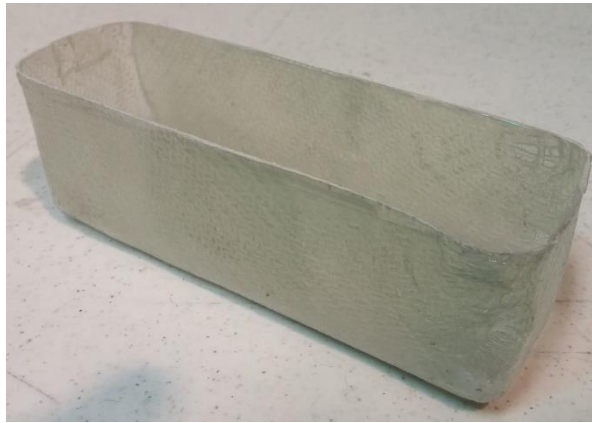


Figure 39. Payload Housing

This fiberglass housing provides sufficient strength while remaining lightweight. Its function is to secure and protect the payload sample throughout launch and flight. Its functionality has been proven through testing using a payload section mock-up.

4 AGSE Criteria

4.1 Science Value

4.1.1 AGSE Objectives

The Autonomous Ground Support Equipment is responsible for the insertion of the payload into the rocket, as well as the placement of the rocket in the proper launch configuration. The entire sequence will be activated remotely and will have a pause function in place for safety reasons. The AGSE shall be able to remain paused for at least one hour and still be able to complete its tasks once the pause ends.

The primary goal of the AGSE is to create a sample recovery system suitable for use on Mars. The ability to retrieve Martian samples and study them in a laboratory environment on Earth will greatly increase our understanding of Mars. The design of the AGSE is compatible for use on Mars because there are no air breathing components and the presence of gravity will allow the AGSE to function similarly to how it would on Earth. This is to be considered a small scale test compared to the size of the rocket needed to escape Mars' atmosphere and rendezvous with a transport spacecraft. The payload would theoretically be delivered by a rover programmed to return to the launch site after acquiring samples.

4.1.2 AGSE Mission

The Autonomous Ground Support Equipment will insert the payload with the use of a Scorbot ER-V and remotely secure the payload within the payload compartment. Then the AGSE system will erect the rocket from the horizontal position to the final launch position, which is 5 degrees from the vertical plane. Upon securing the rocket in the launch position with latches, the AGSE system will then begin to insert the rocket motor igniter. Once the igniter has been inserted the rocket will be ready to launch.

4.1.3 Mission Success Criteria

In order for the project to be successful, the rocket must accomplish certain criteria which will be graded during the competition. These graded events can be found in Table 14 and will determine how success of the project and performance of the team.

Table 14. Success Criteria

Success Criteria	
Event	Goal
Altitude Reached	3000 feet
Timing of System	10 minutes
Launch Angle	5 degrees
Safety Controls	All working
Capture of Sample	First attempt
Sample Containment	First attempt
Erection of Rocket	First attempt
Igniter Insertion	First attempt

4.1.4 AGSE Experimental Approach

The process of designing, programming, and testing each subsystem individually before integrating them into the overall system provides the benefit of being able to ensure that all criteria are met. By having a single subsystem responsible for its own stage in the overall sequence, the process can be observed and altered as needed. For example, if it is determined that the Scorbot is drawing too much power from the source during the payload insertion sequence, the programming can be altered so motion is only occurring on one axis at a time, thereby decreasing energy consumption. Using a single master code to control all subsystems will enable monitoring of the status of each subsystem as it runs as well as the status of the AGSE as a whole unit.

4.1.5 Variable Control

The process of designing, programming, and testing each subsystem individually before integrating them into the overall system provides the benefit of being able to ensure that all criteria are met. By having a single subsystem responsible for its own stage in the overall sequence, the process can be observed and altered as needed. For example, if it is determined

that the Scorbot is drawing too much power from the source during the payload insertion sequence, the programming can be altered so motion is only occurring on one axis at a time, thereby decreasing energy consumption. Using a single master code to control all subsystems will enable monitoring of the status of each subsystem as it runs as well as the status of the AGSE as a whole unit.

4.2 AGSE Design

4.2.1 Tower Structure

The AGSE Tower is composed almost entirely of aluminum, and stands approximately 14 feet tall. The tower structure mimics a ladder design, and incorporates two four-pronged feet to make it a free-standing structure. The feet and the vertical components of the tower are composed of 2x2 inch square tubing. The rungs are made of 1 inch OD aluminum round tubing. Each foot has four horizontal segments and one vertical component, all welded at 90 degree angles. The vertical component of each foot serves as fixing point for rung 1, which serves as a drive shaft. This rung will be held in place by two flange bearings that have been bolted onto the vertical components of the tower feet. The horizontal segments of the tower feet form a cross to maximize stability in all directions. The tower foot design is displayed below in Figure 40.



Figure 40. Tower Foot with Milled Coupler and Flange Bearing

The vertical portion of the tower is divided into two separate pieces: the lower piece and the upper piece. The lower piece is composed of two vertical pieces of 2x2 aluminum tubing, as well as two rungs welded into place. The lower piece is connected to the feet by placing it onto a pair of couplers that are made from aluminum stock that has been milled down to fit within the square tubing. The upper piece is also composed of two vertical pieces of square tubing and two horizontal rungs. However, only the lower rung on the upper piece is welded into place. The upper rung on the upper piece is held into place by a pair of flange bearings. The upper rung will serve as the idler shaft in the system. There are two gears on the idler shaft and three gears on the drive shaft. The ladder structure and gear placement on the idler shaft can be seen below in Figure 41.

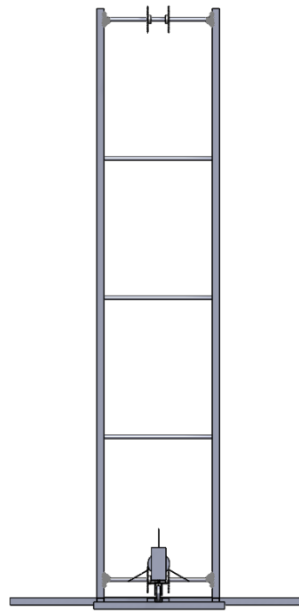


Figure 41. Ladder Design of Tower Structure

Two chains will run in vertically oriented loops from the two gears on the idler shaft, or top rung, to the two outer gears on the drive shaft, or bottom rung. The middle gear on the drive shaft will support a horizontal chain running to the tower motor, located on the aft portion of the tower feet. As the tower motor powers the drive shaft, the vertical chains will rotate. When these chains rotate, they will lift the head of the tower sled upward and the tail end of the sled will roll toward the base of the tower structure. This will erect the sled from horizontal to the launch position. The initial and final configurations are shown below in Figures 42 and 43.

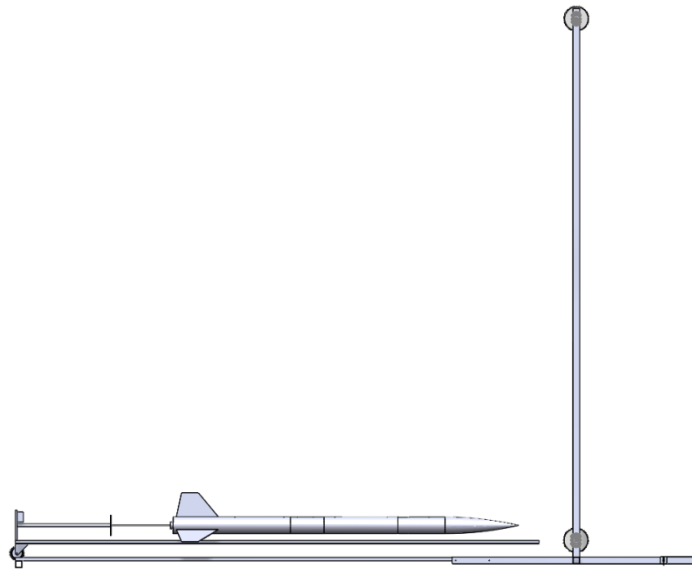


Figure 42. AGSE Loading Configuration

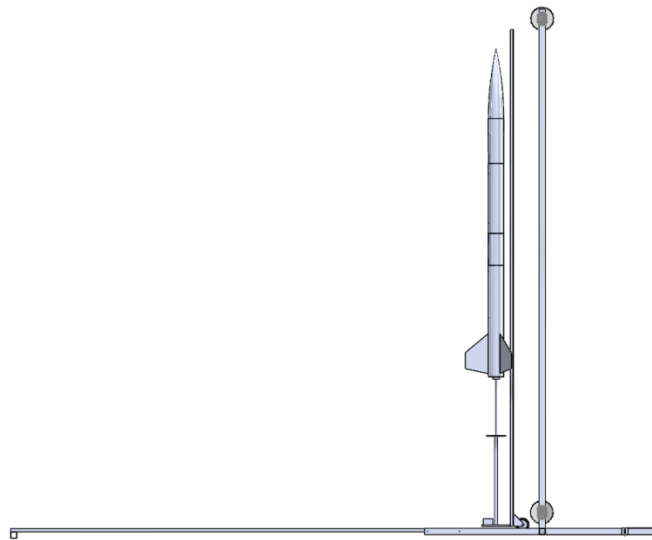


Figure 43. AGSE Launching configuration

4.2.2 Tower Motor and Amplifier

The NPC-T74 was selected based on durability, size, and power output. The motor is advertised to produce anywhere from 26 to 1214 lb-ft of torque and has a durable 20:1 ratio gearbox. The motor itself weighs 14.4 pounds. The amplifier selected for use is an HDC2450 Motor

Controller. This amplifier is capable of controlling the NPC-T74 motor and can be programmed in the field if need be. The HDC2450 comes with all necessary equipment for operation and can be controlled using the AGSE's laptop computer. This amplifier is compact and light, weighing just 3.3 pounds. The challenge of using this subsystem lies within being able to halt the motor's rotation when the rocket has reached the launch position. The most probable solution will be recording the number of cycles completed by the motor during the time it takes to move the rocket from horizontal to 85 degrees. This process will be repeated several times and the results will be averaged to create a standard number of cycles to use within the program. The motor will be bolted to a detachable plate located on the aft portion of the tower structure, shown in Figure 44. The plate will be held in place by 4 pins attached to the cross feet of the tower structure.

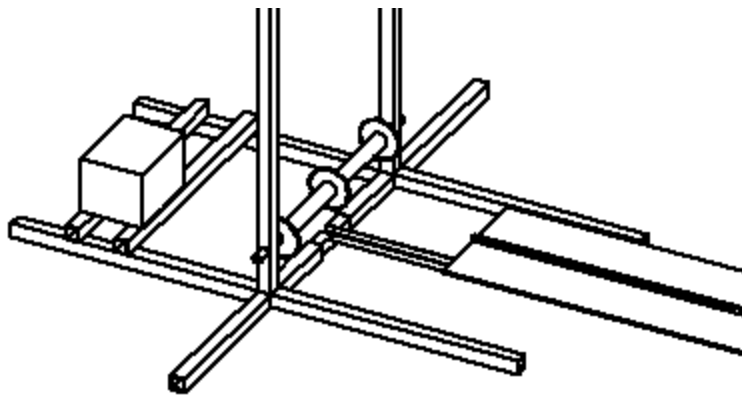


Figure 44. Motor Mount Drawing

4.2.3 Tower Sled

The tower sled, upon which the rocket is placed, is comprised of $\frac{1}{4}$ inch aluminum sheet metal. The sled is 13 feet long and 6 inches wide. In order to maintain stability and prevent bending, a 2 x 2 inch aluminum square tube 12.5 feet long is welded to the bottom of the sheet metal sled, as shown below in Figure 45.



Figure 45. Tower Sled

For strength and transportation purposes, the sled, including the square tube spine, is split into two equal pieces, each 6.5 feet in length. The two pieces are connected together by an aluminum stock coupler milled down to fit within the square tubing. Once inside the tube, the coupler is secured using several stainless steel bolts. At the end of the sled, where there are 6 inches of sheet metal not covered by the 12.5 feet spine, there are two standard caster wheels, each bolted to the aluminum sheet 1 inch from the centerline. These wheels run in the two tracks attached to the tower structure. On the other end of the sled are fixed two eyebolts with the rings 1.0625 inches in diameter. These eyebolts are attached to the sled connector tube which is shown below in Figure 46.



Figure 46. Sled Connector

The connector tube shown in Figure 46 is made of 1 inch OD aluminum round tubing and is 8 inches in length. Eight circular holes have been drilled through the wall of the tube. The holes are located 1 inch from both ends of the tube, and are spaced at 90 degree intervals. The top and bottom holes, through which the chain runs, are 0.5 inches in diameter. An 8-32 bolt, 1.5 inches long, is placed through the two smaller horizontal holes, also passing through a link in the chain inside the tube. These two bolts serve to hold the tube to that place on the chain. The sled is attached to this tube by placing the tube through the rings of the two eyebolts. This freely rotating connection allows the sled to change angle and keep its wheels in the tracks as it is being brought up the face of the tower. The launch rail and the igniter insertion device are bolted to the top of the sled, with the igniter insertion device located at the end with the wheels.

4.2.4 Scorbot ER-V

A Scorbot ER-V will be integrated into the AGSE because of its durability and simplicity. This particular Scorbot model is capable of lifting up to 2.2 pounds and has a wide enough range of motion to handle the payload insertion process. The Scorbot's range of motion as advertised in the Scorbot ER-V user manual is displayed below in Figures 47 and 48.

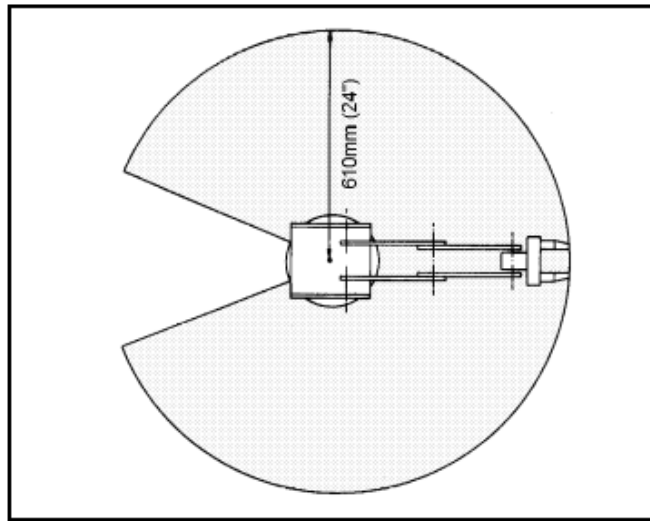


Figure 47. Top-down View of Scorbot Operating Range

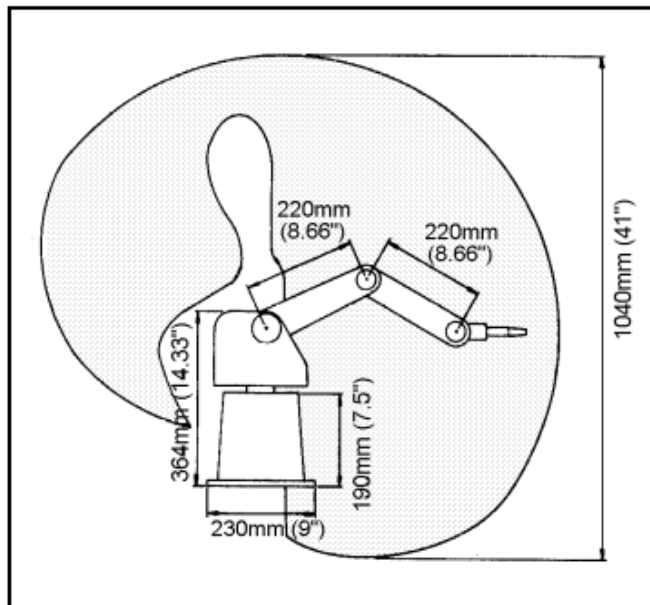


Figure 48. Side View of Scorbot Operation Range

The Scorbot will be placed on the ground and staked into place next to the opening of the payload bay. A series of waypoints will be determined and programmed once the Scorbot is in place. This programming phase will be completed each time the system is set up to ensure maximum accuracy in the payload insertion phase. The Scorbot will pick up the payload and carry it through each waypoint before placing it into the payload bay. The Scorbot will then return to the starting position after the payload has been inserted.

4.2.5 Igniter Insertion Device

Fixed to the bottom of the rocket sled, below the rocket nozzle, is a flat plate on which the igniter insertion system will be mounted as shown in Figure 49. The igniter insertion system consists of a Firgelli Automations 24 inch stroke, 150 pounds force linear actuator, a flat circular steel plate, and an 18-inch aluminum rod of $\frac{1}{4}$ inch outer diameter mounted onto the end of the extendable shaft. The rod is threaded and screws in to the extendable shaft so it can be removed as necessary to avoid damage to the structure of the system.

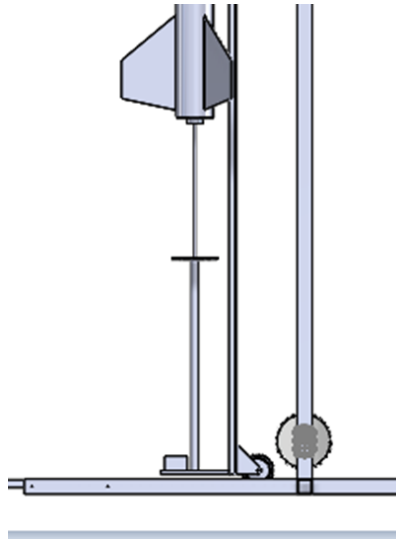


Figure 49. Igniter Insertion Drawing

The ignition wire runs from a hole in the base of the rod to the top of the rod below the nozzle. The igniter is exposed at the end of the tube, facing towards the rocket. The un-mounted igniter insertion system can be seen below in Figure 50.



Figure 50. Un-mounted Igniter Insertion System

The linear actuator is powered by a mounted 12-volt DC motor that draws a maximum of 5 amps powered by the AGSE power source. The automated portion of the actuator will be controlled by a Roboteq SDC1130 Single Channel Forward/Reverse Brushed DC Motor Controller. The Roboteq will be programmed using Matlab on the laptop to insert the rod with the igniter on the end to the top of the rocket's engine. The linear actuator will be mounted to the base of the tower sled using a system of bolts and spacers. The threaded rod will screw into the end of the actuator's arm so it can be easily removed. The DC motor is pre-mounted on the linear actuator.

4.3 AGSE Configuration

The initial tower configuration will have the rocket lying horizontally, with the payload bay open. The Scorbot shall be placed so that the edge of the base is 12 inches in the horizontal direction from the centerline of the rocket, near the payload bay. A diagram of the Scorbot is shown below in Figure 51.

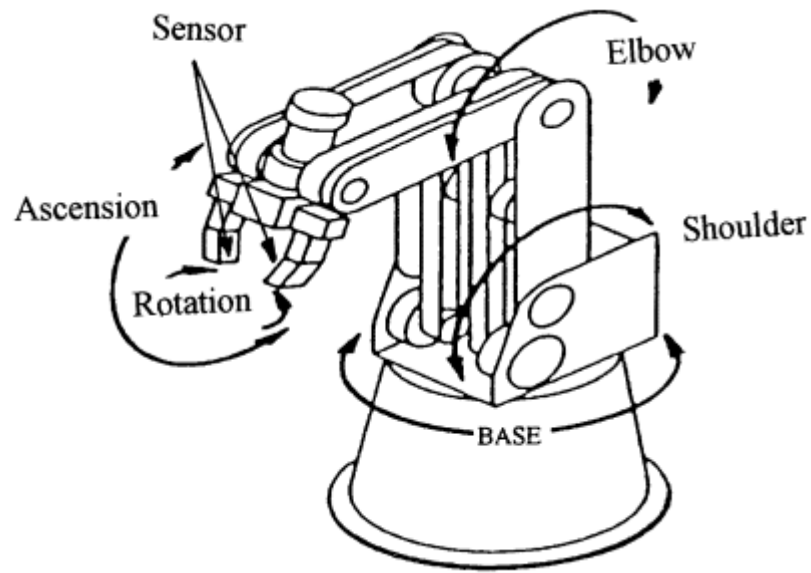


Figure 51. Scorbot ER-V

This will provide ample space for the tower to erect the rocket without coming into contact with the Scorbot. The Scorbot will begin with the arm facing away from the rocket, and the tip of the gripper shall rest no more than 4 inches above the ground. The payload will be on the ground directly below the Scorbot gripper. The longitudinal axis of the payload shall be parallel to the longitudinal axis of the rocket body.

All components of the AGSE, excluding the laptop and corresponding transmission devices, will be powered by a high performance 12 volt, 75 AH battery. The power supply will be regulated to meet the needs of the Scorbot, tower motor, and igniter insertion device. The power drawn from the supply by each device will be measured during the testing phases of each respective component. A voltage indicator will be used to monitor the status of the battery. An added benefit of running each system individually during the AGSE sequence of events is minimizing the amount of power being drawn from the supply at any given time.

4.3.1 Assembly

A checklist has been established in order to complete the entire AGSE assembly procedure:

1. Slide track coupler into short segment of foot A. Secure with bolts.
2. Slide other side of track coupler into short segment of foot B. Secure with bolts.
3. Slide tower segment C onto the stock couplers protruding from both foot A and foot B. Secure with bolts.
4. Slide tower segment D onto the stock couplers protruding from the top of ladder segment C. Secure with bolts.
5. Loop chains from gears on top rung to outer gears on lowest rung. Secure with connecting link to form full loop.
6. Adjust chain tighteners as need to remove slack.
7. Place motor on back portion of tower feet and secure with 4 quick release pins.
8. Loop chain from middle gear on lowest rung to the motor gear. Secure with connecting link to form full loop.
9. Slide the rocket onto the launch rail.
10. Connect sled to chains. Tighten connector nuts to secure the sled. Ensure that each wheel is on its respective track.
11. Place Scorbot on ground 12 inches from payload bay. Secure with 4 stakes.
12. Place Scorbot driver as far from the Scorbot arm as the cable will allow.
13. Run igniter wire through insertion tube.
14. Connect all systems to the power source.

4.3.2 Instrument Precision

The laptop computer utilized by the AGSE will control and monitor all subsystems through the use of MATLAB. The Scorbot control unit will relay feedback to the program to indicate the position of the Scorbot arm throughout the insertion process. Encoders the various motors used will indicate when they have completed their respective rotations or extensions. The position repeatability of the Scorbot is advertised to be 0.5 mm or 0.02 inches at the tip of the gripper. This satisfies the requirement that the payload is placed within 0.5 inches along the longitudinal axis of the rocket and 0.3 inches left or right of the centerline of the intended payload insertion position. The AGSE shall erect the rocket to no less than 85 degrees to avoid improper locking of the gate latches. If intended 85 degree mark is not reached, the rocket sled will fail to lock into position. If the tower sled is erected to more than 85.5 degrees, the brackets securing the gate latches could be damaged. The linear actuator incorporated by the igniter insertion must insert the igniter within -0.5 inches to avoid over insertion and potential damage to the insertion unit.

4.4 Testing and Verification Plans

The Scorbot testing phase will be done using only the full scale version of the AGSE system. The Scorbot will initially undergo independent testing. The testing will be conducted using a dummy payload composed of PVC pipe and sand filling, designed and built from the engineering

drawings for the project shown in Figure 52. A mock payload bay will be constructed with PVC and wood. The Scorbot positions will be determined and programmed. The Scorbot will then run 50 cycles and the results for all of the iterations will be recorded. In order to consider the testing to be a successful, 45 of the 50 cycles must effectively insert the payload into the mock payload bay. Power consumption by the Scorbot will be measured and analyzed. When the testing is deemed successful, the Scorbot will be ready for use with the tower and rocket. An initial program designed to test the Scorbot's capabilities and range of motion has been successfully written and tested.

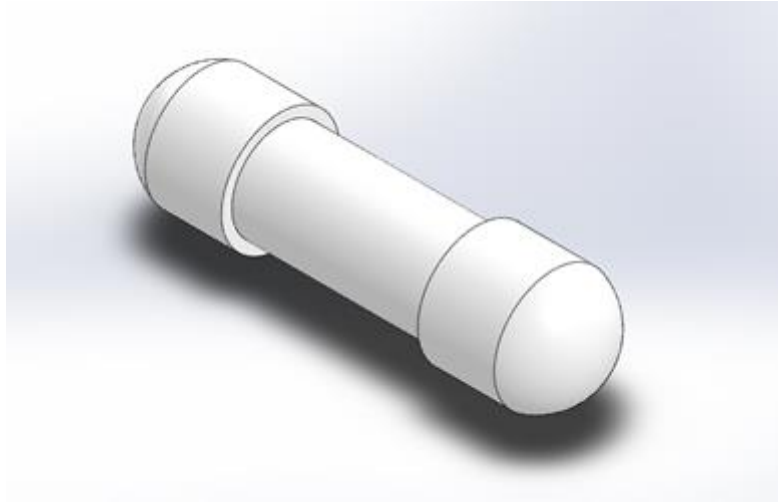


Figure 52. Payload Tube

Once the tower structure has been completed, it will initially undergo testing without the use of the Scorbot or rocket. At least 10 rounds of testing will be done to ensure that the tower can successfully raise the rocket sled to the launch configuration and lock the rocket sled in place. The tower must successfully erect the sled 10 consecutive times to be considered successful. Upon determination of the tower's capabilities, the rocket will be mounted to the sled. The tower structure will then undergo another 10 rounds of testing with the added weight of the rocket. Power consumption by the tower motor will be measured and analyzed for integration with the rest of the AGSE.

The igniter insertion device will initially undergo testing with a dummy rocket. The rocket will have the same physical characteristics as the real rocket, including motor bore diameter. The igniter insertion device will be tested 10 times to determine if it can successfully insert a wire into the dummy rocket. 10 of the 10 rounds must result in successful wire insertion. Although the power consumed by the igniter insertion device will be miniscule by comparison to the rest of the AGSE components, it will still be measured and analyzed to ensure compatibility.

Once all three components of the AGSE have been deemed fully functional, they will be tested together to mimic the actual scenario. First, the Scorbot will insert the payload into the payload bay. The rocket will then seal the payload bay. The tower structure will then erect the rocket.

When the rocket sled is locked into place, the igniter insertion device will insert the igniter into a dummy motor that has been temporarily placed within the rocket. All aspects of the AGSE, including the safety functions and status indicator lights will be tested during this phase. This process must be completed successfully at least 10 times in order to deem the AGSE compliant with all requirements and ready for use with a live rocket.

4.5 AGSE Integration

4.5.1 Integration Plan

All components of the AGSE will be controlled via a laptop computer running MATLAB, and by extension, a switch box with three buttons. The first button will control the power supply to all elements of the AGSE. The second button will activate the AGSE payload insertion and rocket erection process. The third button will temporarily terminate all functions of the AGSE. When the run button is pressed, the laptop will send commands to the Scorbots to initiate the payload insertion process. When the Scorbots have completed their series of events, the laptop will send a command to the payload bay after a 10 second delay. The signal will be sent via radio frequency transmitter. When this signal is received by the payload bay, the payload will be secured and the payload bay will close. There will be a 10 second delay once the payload bay is closed. At the end of the 10 second delay, the laptop will send a command to the motor system via transmitter to erect the rocket. Contained within the motor-driver system will be an encoder unit that will relay information back to the laptop, including a signal to indicate when the rocket has reached its final position. The number of motor wheel rotations required to erect the rocket will be determined during the testing phase. When this completion signal is received by the laptop, a signal will be sent to the igniter insertion device via RF transmitter. A micro switch on the igniter insertion device will return a signal indicating completion of the igniter insertion process. Pressing the pause button at any time during this series of events will stop all processes. Lights will indicate when the AGSE is carrying out the assigned tasks, as well as when the process is complete and the system is ready for launch. The use of several transmitters ensures that any unwanted communication between separate subsystems will be avoided. Limiting the AGSE to one task at a time will minimize the risk of compounding any errors and will simplify the troubleshooting process. Any error can be traced back to the single subsystem that will be operating during the time of the incident. Thus far, no changes have been made to the integration plan. The AGSE layout is displayed below in Figure 53.

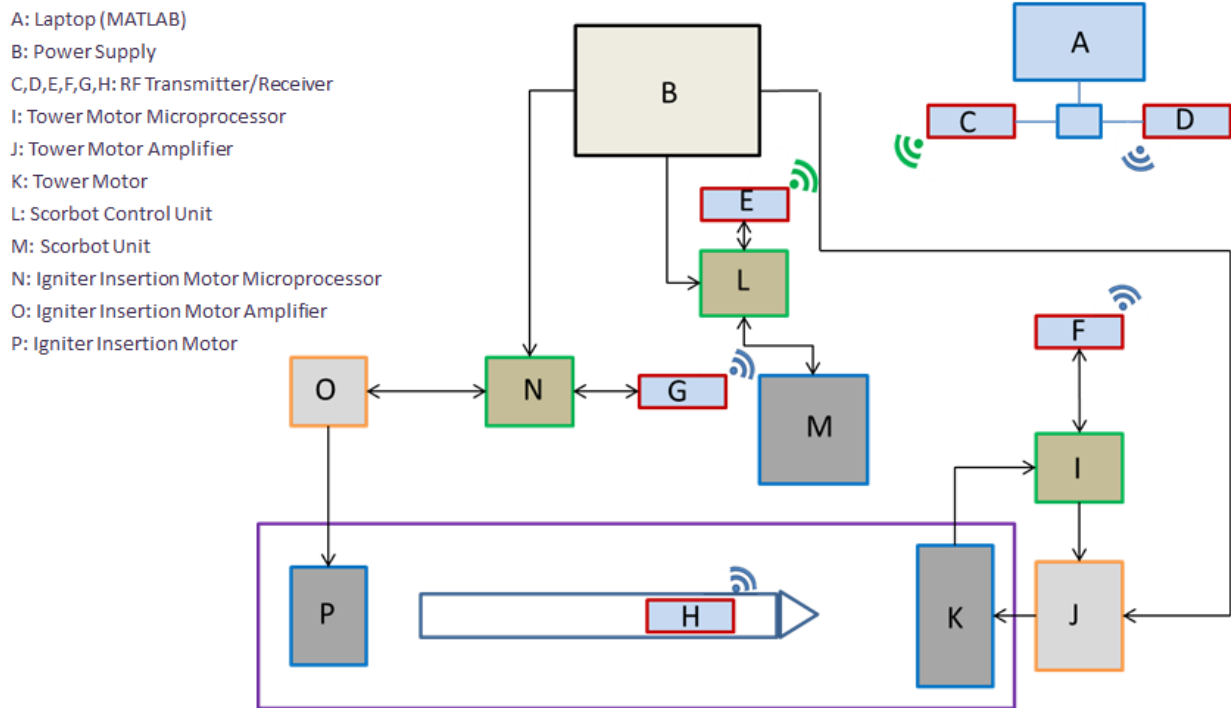


Figure 53. AGSE Schematic

Unit C will communicate with unit E to relay commands to the Scorbot control unit. Unit E will relay feedback back to unit C to signal when the Scorbot has completed motion sequence. Unit D will communicate with units F, G, and H. Commands to the payload bay concerning the securing of the payload and the closure of the payload bay will be sent from unit D to unit H. Feedback stating when these tasks are complete will be returned. Unit D will communicate with unit F to control the tower motor. When the rocket has reached the 85 degree launch angle, motor rotation will cease and unit F will relay a signal back to unit D stating that the process is complete. Following this, unit D will relay commands to unit G to begin the igniter insertion process. Feedback will indicate when the igniter has been fully inserted. All processes will occur in this order, one at a time. The logic behind dedicating unit C solely to the Scorbot sequence is to eliminate the risk of crosstalk interfering with the idle state of the Scorbot. If the Scorbot were to receive a command intended for a different AGSE component, it will relay an error message and interfere with the feedback from the other Rx/Tx units.

4.5.2 AGSE Timeframe

The AGSE will conduct its operations during several separate stages, with delays in between stages. The entire process shall take no more than 7 minutes, excluding the countdown to launch. A breakdown of the timeframe is shown below in Table 15.

Table 15. AGSE Timeframe

<i>Event Number</i>	<i>Event</i>	<i>Event Time (min:sec)</i>	<i>Total Time Elapsed (min:sec)</i>
1	Payload Insertion	0:30	0:30
	Delay	0:10	0:40
2	Payload Securement	0:10	0:50
3	Nosecone Closure	1:10	2:00
	Delay	0:10	2:10
4	Tower Erection	3:00	5:10
	Delay	0:10	5:20
5	Igniter Insertion	1:40	7:00
6	Launch	TBD	7:00+

4.6 Verification

4.6.1 Requirement Verification

Navy Rockets have completed and verified all AGSE requirements for the project. The list of requirements and verification methods can be found in Appendix D.

4.7 AGSE Safety

4.7.1 Safety Analysis

Several safety mechanisms are built into the integration plan in the event of a system failure. A master switch is hardwired to the AGSE in order to control the battery power to the various systems. Another switch is used to pause all actions performed by the AGSE during any point of the operation. This switch is also hardwired to the AGSE to prevent any error that could stem from a wireless connection. Visual confirmation of the state of these switches is included in the form of safety lights. An amber/orange light flashes at a frequency of 1 Hz to indicate that the AGSE is powered on and remains unlit when the power is off. When the pause switch is engaged, the light stays on constantly. A green light is used to show that all the various systems on the rocket and tower have passed safety verifications and the entire system is ready for launch. Along with this safety light system, several controls have been put in place in the event of a system failure. The most likely failures based on the AGSE design are shown in Table 16.

Table 16. Failure Modes and Effects Analysis

<i>Failure Mode</i>	<i>Cause</i>	<i>Likelihood</i>	<i>Severity</i>	<i>Mitigation</i>
Sled disconnecting from tower chains during rocket erection	Shearing of the two bolts holding the connector tube to the chains	Low	High	Bolts connecting the tube to the chain are high strength stainless steel rated for over 500 lb. loads
Ignition failure	Igniter tube fails to enter the rocket motor properly	Low	Low	Igniter tube is small enough in diameter to prevent choking and the insertion is thoroughly tested to ensure functionality
Tower falls or sways	Unstable environmental conditions such as wind or severely uneven ground	Low	High	The small surface area and cross section of the tower make it highly unlikely that it will topple due to wind. If the ground at the launch site proves to be detrimentally uneven, stakes will be used to hold the tower securely in place.
Chain system snaps	Loads on the chain become too high and shears the chain links	Medium	High	The chain used on the tower structure is rated for loads up to 200 lbs., far heavier than the rocket and sled combined
System malfunction	Error in the coding or communication between sensors	Low	High	Install a pause switch and test the frequencies transmitting information

4.7.2 Personnel Hazards

The AGSE personnel hazards can be seen in Table 17. These hazards have been considered dangerous but mitigation plans have been developed to ensure safety to all around and operating the equipment.

Table 17. AGSE Personnel Hazards

<i>Hazard</i>	<i>Mitigation</i>
During setup, the tower could collapse and fall on a team member.	The tower system is split into many parts to make it more manageable, leaving no overly heavy or long sections. Each piece is secured in place with either bolts or solid couplers, making a collapse highly unlikely.
Launch rail or sled slips, causing rocket to point towards personnel during launch.	The launch rail is securely bolted to the sled and highly unlikely to become loose. The sled is securely held in place when it reaches the desired angle of 5 degrees from the vertical. If all else fails, the master switch would halt all operations.
Personnel unknowingly approach the tower while it is powered on and igniter is inserted	Lights on the tower clearly indicate the state of the system, warning any personnel. Conforming strictly to launch procedures will also mitigate this risk.

4.7.3 Environmental Concerns

The AGSE does not pose a threat to the environment so long as all components are retrieved after launch. The stakes used will not damage the soil beneath the system. All necessary precautions will be taken to ensure that any lubricant used does not spill onto the soil.

5 Launch Operations

5.1 REPTAR Checklists

5.1.1 *Pre-flight Brief*

Before any rocket launch, Navy Rockets will go over the Pre-flight Brief. This brief will be given by the Safety Officer and will discuss the flight plan and any concerns that arise that day.

1. Launch Overview
 - a. Motor Selection
 - b. Launch Goals
 - c. Predicted Outcomes
 - d. Avionics Test
2. Weather
 - a. Launch Concerns
3. Rocket Performance
 - a. Weight
 - b. Predicted Altitude
4. Flight Conduct
 - a. Drogue Deployment
 - b. Main Deployment
 - c. Tracking Systems
5. Safety
 - a. IMSAFE Concerns
 - b. ORM Concerns
 - c. Safety Concerns
6. Emergencies
 - a. General Emergencies
 - b. Hazards and Mitigation
 - c. Emergency Contact
7. RSO
 - a. Location Rules
 - b. Launch Check

5.1.2 Recovery Preparation

1. Lay out all parachute and recovery harness lines.
2. Inspect harness elements to ensure no tangles, twists, or tears in parachute cloth, shrouds, or harness lines.
3. Assemble full harness by attaching all carabineers, harness loops, and parachute swivels.
4. Ensure parachute protectors are in correct location on harness.
5. Roll parachutes and lines in an orderly pre-determined fashion to eliminate tangles upon deployment.
6. Check all connection points and carabineer screw gates.
7. Position the protectors inside parachute housing compartments.
8. Install new 9V batteries into altimeter power clips.
9. Ensure each altimeter powers on.
10. Ensure each GPS unit powers on and is transmitting.
11. Seal avionics compartment.
12. Following all safety precautions, load black powder into ejection canisters.

Before Launch:

1. Engage master arming switch in locked “armed” position.
2. Ensure both exterior LED lights function and flash correct battery voltage.

5.1.3 Motor Preparation

1. Remove ejection charge from motor.
2. Insert K1200 motor into casing.
3. Insert the motor and casing into the motor retention.
4. Ensure that the igniter insertion receives the igniter.

5.1.4 AGSE Assembly Setup

1. Slide track coupler into short segment of foot A. Secure with bolts.
2. Slide other side of track coupler into short segment of foot B. Secure with bolts.
3. Slide tower segment C onto the stock couplers protruding from both foot A and foot B. Secure with bolts.
4. Slide tower segment D onto the stock couplers protruding from the top of ladder segment C. Secure with bolts.
5. Loop chains from gears on top rung to outer gears on lowest rung. Secure with connecting link to form full loop.
6. Adjust chain tighteners as need to remove slack.
7. Place motor on back portion of tower feet and secure with 4 quick release pins.

8. Loop chain from middle gear on lowest rung to the motor gear. Secure with connecting link to form full loop.
9. Slide the rocket onto the launch rail.
10. Connect sled to chains. Tighten connector nuts to secure the sled. Ensure that each wheel is on its respective track.
11. Place Scorbot on ground 12 inches from payload bay. Secure with 4 stakes.
12. Place Scorbot driver as far from the Scorbot arm as the cable will allow.
13. Run igniter wire through insertion tube.
14. Connect all systems to the power source.

5.1.5 Launcher Setup

Setup of the AGSE will begin with the assembly of the tower structure. The upper and lower components of each tower will be pinned together. The rocket sled and track will then be put into position between the two sides of the tower structure. The igniter insertion system is permanently attached to the sled. The tower rungs and chains will be pinned into place, connecting the two sides of the tower structure and fixing the sled track into place. Next, the tower motor will be pinned to the back of the tower structure. All chains will be properly mounted on their respective gears. When this is complete, the rocket sled will be connected to the vertically oriented chain system. The Scorbot will be placed on the ground, adjacent to the payload bay area. All components will then be connected to their respective power source and powered on. All subsystems will be tested to ensure that they are functioning correctly. Following this, the rocket sled will be detached from the tower and the rocket will be fed into the launch rail on the rocket sled. The rocket sled will then be reattached to the tower and the payload bay will be opened. The sample will then be placed on the ground, beneath the Scorbot gripper.

1. Ensure Scorbot is powered on.
2. Enable the homing function from the command laptop.
3. Set waypoints.
4. Test waypoints without payload to ensure full range of motion and gripper capabilities.
5. Spray gate latches on the tower with lubricant.
6. Make sure tower motor has power.
7. Make sure igniter insertion device has power.
8. Make sure all RF units have power.
9. Make sure exposed portion of igniter wire is not bent or broken.

5.1.6 Igniter Installation

Once the rest of the AGSE is assembled, the igniter insertion device will be in place since it is attached to the base of the rocket sled. It will be verified that the igniter insertion device is properly aligned with the center of the rocket motor bore. The igniter insertion device, with its linear actuator, will be tested in place on the AGSE for proper operation. Once proper operation

is ensured, the igniter insertion device will be considered ready for launch. During the actual launch process, the igniter insertion device will receive the command from the AGSE control element and insert the igniter into the rocket motor.

1. Ensure igniter insertion device is secured to sled.
2. Ensure threaded rod is secured to actuator.
3. Visually inspect threaded rod to ensure that it is not bent.
4. Ensure that any exposed igniter wire does not come into contact with any metal.

5.1.7 Launch Procedure

1. Payload insertion
2. Payload securement
3. Nose cone closure
4. Tower erects
5. Igniter inserted
6. Rocket launches

5.1.8 Troubleshooting

Any problems that occur during the set up and launch of the rocket will be discussed with the team, our faculty representative, and our rocketry mentor. With each team member focusing on a specific area it allows Navy Rockets to have an idea on all of the topics that require work. By utilizing the faculty representative and also the rocketry mentor it enables more knowledge to be used in order to fix the problem.

1. Locate the cause of failure.
2. Ensure that the igniter is removed and electronics disarmed before working on the problem.
3. Section expert discusses problem with faculty and mentor to determine the plan of attack.

After Problem Corrected:

1. Check AGSE connections and system launch progress.
2. Check igniter insertion and continuity before launching.

5.1.9 Post-flight Inspection

1. Locate sections of the rocket.
2. Record altitude off of main avionics.
3. Turn off electronics
4. Check for extra black powder/ remove motor
5. Secure all sections
6. Examine structure

Once the launch vehicle payload section has landed and been recovered, the control computer of the AGSE will be used to send an “Open” command to the payload section via wireless transmission. This command will activate the DC motor to open the payload section and then activate the servomotor to retract the payload securement tab. At this point, the standardized payload sample will be removed from the payload section of the rocket. The checklist for this procedure is as follows:

1. Inspect launch vehicle payload section for integrity and proper orientation.
2. Use AGSE control computer to send “Open” command to payload section.
3. Inspect interior of payload section for integrity.
4. Remove standardized payload sample.

After AGSE payload recovery:

1. Debrief flight conduct
2. Performance overview
3. Lessons learned

5.2 Safety and Quality Assurance

5.2.1 Safety and Quality Inspector

Navy Rockets’ Safety Reliability and Quality Assurance (SRQA) chief, Cole, will conduct all inspections of the rocket, AGSE, and environment. Cole will conduct safety briefs to ensure that the team complies with all rules and regulations and also attempt to reduce any risk from working. The SRQA chief has final say on operations that may become unsafe, however the team is encouraged to alert everyone if they feel something becoming unsafe.

5.2.2 Safety Analysis

5.2.2.1 Laws

The Navy Rockets team understands the laws that govern high power rockets. This includes the FAA regulation on airspace, the Federal Aviation Regulation 14 CFR: Subchapter F: Part 101: Sub-part C, the Code of Federal Regulation 27 Part 55, and the code for the use of low-

explosives: NFPA 1127 Code for High Power Model Rocketry. This information can be found in Appendix E.

All of the flight testing and some ground testing for the project will be done with MDRA at their launch sites. MDRA has a FAA flight waiver for an altitude of 17,000 feet every weekend of the year. This allows Navy Rockets to be able to launch whenever testing needs to be completed on both the sub-scale and full-scale launches. MDRA has a goal for zero injuries to occur during their launches, the group has multiple, qualified Range Safety Officers that ensure everyone is adhering to the rules.

5.2.2.2 MSDS

Many of the material used during the competition have hazards associated with them. A list of potential material hazards can be found in Appendix F on the material hazards before they are used on any part of the project by the Safety Officer.

5.2.3 Operational Risk Management

Although the team focuses on safety, some of the activities can still be dangerous to the team or equipment. Due to the team's military ties, the United States Navy's Operational Risk Management (ORM) system was used to rate the hazards and failure modes for Navy Rockets. Each situation requires a probability and severity, which can be seen in Figure 54. The probability assigns a letter A-D with A being highly probable and D most likely not occurring. The severity column assigns a number I-IV with I(1) being extremely dangerous and IV(4) being no threat of danger. The ORM is then complete by using the risk matrix, shown in Figure 55. The number value and letter that were found from Figure 55 are then used in the risk matrix to determine the risk assessment code. This code is assigns a number 1-5 and is color coded to ensure that the assessment is known. For the code, a value of 1 is red and a critical situation which means that it is high probability of a high severity. A value of 5 is almost no risk and means that it is not sever or probable. The hazards and failure modes can be found in Tables 18-24.

Probability	Severity
A - Likely to occur immediately or within a short period of time.	I - May cause death, loss of facility/asset.
B - Probably will occur in time.	II - May cause severe injury, illness, property damage.
C - May occur in time.	III - May cause minor injury, illness, property damage.
D - Unlikely to occur.	IV - Minimal threat.

Figure 54. ORM Values

		Probability			
		A	B	C	D
Risk Assessment Code	Severity I	1	1	2	3
	Severity II	1	2	3	4
	Severity III	2	3	4	5
	Severity IV	3	4	5	5

1 = Critical
2 = Serious
3 = Moderate
4 = Minor
5 = Negligible

Figure 55. ORM Risk Matrix

Table 18. Hazard Analysis for Project and Safety

Hazard	ORM Value	Cause	Effect	Mitigation	Verification
Project					
Over budget	2	Not paying attention to where money is being spent; spending money on items that are not necessary or could be purchased for cheaper.	Could run out of money at the end of the project that could have been used to fix a last-minute problem or emergency.	Maintain detailed budget records and hold individuals accountable for money that is spent. Do thorough research on the most cost effective ways to purchase materials.	Specific individual designated to maintain budget records. Thorough research on alternative costs completed.
Fall behind on the schedule	3	Lack of focus and "big picture" oversight; procrastinating on projects; not paying attention or adhering to set deadlines.	Quality of project could decrease overall, threatening performance at final competition. Could not finish on time and therefore not be able to compete.	Leadership maintain constant oversight on set timeline; hold team members accountable for project deadlines. Try to finish projects ahead of schedule and don't procrastinate.	Team leader held responsible for schedule.

Material not available	2	Sometimes out of team's control; other times could be a result of procrastination, leading to limited options.	Could force team to use materials that aren't the most ideal for a certain part of the project. In a worst-case scenario, a crucial material could be unobtainable and the project could fail.	Do not procrastinate in obtaining materials. Have backup materials available, especially if they are crucial to the project's success.	All materials obtained early as well as backup materials.
Material damaged during testing	2	Variety of potential causes, ranging from unavoidable accidents to user error.	Could delay project progress, could cause project to fail if it happens at a crucial time during the end or at the competition. Could force redesign.	Have backup materials available to fix any damaged ones. Have alternate designs prepared in the event a redesign is necessary.	No damage done yet, but backups available to vulnerable parts.
Machines breakdown	4	Machines not properly taken care of or are used improperly.	Could delay the building and manufacturing process of the project.	Follow all machine shop rules and ensure that the correct machines are used for specific materials.	Machine shop tools only operated under proper supervision and authority.
Team fails to communicate	4	Schedule becomes busy and then failure to update team on progress occurs.	The team falls behind on building and then misses deadlines for the project.	Have weekly meetings to discuss what each person is working on and the progress on their sections.	Maintained open communication by meeting as a team three times per week before splitting up to complete tasks.

Table 19. Hazard Analysis for Vehicle Safety

Hazard	ORM Value	Cause	Effect	Mitigation	Verification
Vehicle					
Parachute fails to deploy	2	Poor packing, damage on launch, environmental circumstances at deployment altitude.	Rocket falls uncontrollably, potentially causing project-ending damage.	Ensure parachute is packed properly, test repeatedly before competition to determine best packing configuration.	Parachute packed very carefully under experienced supervision.
Parachute catches on fire	3	Poor packing or not enough protection from the motor.	Rocket falls uncontrollably, potentially causing project-ending damage.	Ensure parachute is packed properly and place fire retardant material between them and the motor.	Sufficient fire-retardant material packed between parachute and motor.
Parachute lines tangled	4	Poor packing of the parachutes	Rocket falls uncontrollably, potentially causing project-ending damage.	Ensure parachute is properly packed.	Parachute lines wrapped gently and cautiously.
Sections fail to separate	2	Sections initially connected improperly, damage on liftoff, environmental circumstances at deployment altitude.	Rocket does not perform to project standards, potentially causing project-ending damage.	Ensure sections are connected properly. Test connections repeatedly before competition to determine best connecting process and configuration	Couplings inspected before launch for proper friction to ease separation.

Parachute separates from rocket	2	Poor packing, damage on launch, environmental circumstances at deployment altitude.	Rocket falls uncontrollably, potentially causing project-ending damage.	Ensure parachute is packed properly, ensure separation works before competition, test repeatedly before competition to determine best packing configuration.	Parachute packed cautiously and under supervision.
Altimeter fails to work	3	Not enough power or faulty wiring systems.	Rocket will not deploy parachutes at the proper altitude.	Redundant systems are utilized in order to ensure the altimeters function properly.	Learned from previous altimeter failures and implemented new methods to ensure proper use based on prior failures.
Stability margin is too small	4	The CG shifts too close to the CP from bottom loading the rocket.	The stability of the rocket decreased which can harm the flight path and performance.	Ensuring that the weight balance is correct and verified with Open Rocket data.	Weight balance double checked prior to launch.
Structural failure	2	A defect during the building process or potential damage during launch operations.	The rocket will not be launch ready or not able to be launched again.	Careful manufacturing of the rocket and strength testing to ensure it can withstand the required loads.	Rocket sustained all structural loads during test launches.
Payload section fails to close	2	The payload section jams or will not secure properly.	The rocket will not be safe to launch and the payload could fall out.	Testing and inspecting the payload section to ensure that everything works properly.	

Early section separation	3	The connection points are not strong enough to hold the rocket together.	Rocket does not reach required altitude or damages itself during flight.	Testing of the connection points as well as full scale testing of the rocket separating.	Couplings checked for proper connection friction to prevent early separation.
Delayed section separation	4	The connection points are too strong holding the rocket together and will not allow it to separate.	Rocket will not deploy parachutes at the proper altitude.	Testing of the connection points as well as full scale testing of the rocket separating.	Couplings checked for proper connection friction to prevent early separation.
Bulkhead failure	3	The bulkhead breaks from the ejection canisters pressurizing the tube or from the recovery system causing too much stress.	Rocket will not deploy parachutes at the proper altitude or will split into pieces and be a hazard while landing.	Testing the strength conditions of the bulkheads to ensure they can withstand heavy loads.	Bulkheads secured with epoxy
Systems lacking enough power	4	The batteries are not fully powered or wired incorrectly.	The rocket systems will not function properly and may cause damage to the rocket.	Test the circuitry and also put in new batteries before launch.	
Recovery system lines fail	4	Cord and wires are not secured properly or are damaged.	Rocket will not be safe when it deploys parachutes causing the landing to be hazardous.	Test and check all of the recovery harnesses prior to launch.	All components of recovery system double-checked and reinforced.
Avionics will not track	5	Possible loss of rocket due to winds.	Unsuccessful rocket recovery.	Test the GPS system to ensure that it is functioning properly.	GPS functioned perfectly on testing.

Table 20. Hazard Analysis for the AGSE System

Hazard	ORM Value	Cause	Effect	Mitigation	Verification
AGSE					
AGSE drops sample	2	Poor coding, motor issues, power issues, environmental issues.	Cause failure of competition	Repeatedly test AGSE operation; work out all issues before competition day	
AGSE loses communications link	2	Power issues, external wireless interference	AGSE stops working, causes failure of competition	Ensure nearby wireless radios are turned off so as to not interfere with AGSE communications link	
Igniter does not insert	3	Power issues or the interfaces are not working properly.	Cause failure of competition	Test the igniter system to ensure that it functions properly.	

5.2.4 Personnel Hazards

During the Student Launch Project potential hazards could and have developed. These hazards and mitigations can be found in Tables 21-22.

Table 21. Hazard Analysis for the Student Launch Project

Hazard	ORM Value	Cause	Effect	Mitigation	Verification
Launch					
Rocket fails to be erected	3	Faulty coding, faulty motor, power source error, etc.	Rocket cannot be launched	Repeatedly test rocket erection prior to competition so as not to have any issues on launch day. Perhaps compose a checklist to ensure no important steps are forgotten.	
Rocket fails to leave the stand	3	Motor issues, power issues	Rocket cannot be launched	Repeatedly test launch procedures prior to competition so as not to have any issues on launch day. Perhaps compose a checklist to ensure no important steps are forgotten.	Stand thoroughly checked before launch.
Igniter fails to ignite motor	3	Igniter issues, motor issues, power issues.	Rocket cannot be launched	Repeatedly test motors prior to competition so as not to have any issues on launch day. Perhaps compose a checklist to ensure no important steps are forgotten.	Igniter placement double-checked before launch.
Catastrophic motor failure	3	Faulty motor or mishandling during traveling.	Rocket destroys the frame and possibly damages the system.	Ensure properly storage and handling of the motor.	Motor handled very carefully.

Table 22. Safety Concerns for the Student Launch

Hazard	ORM Value	Cause	Effect	Mitigation	Verification
Safety					
Chemical Burns	1	Poor handling of dangerous materials, poor oversight from leadership responsible for safety, lack of knowledge about dangers of materials.	Could cause severe injury to crucial team members, thus placing more workload on other members, decreasing the overall quality of the output of their work.	Educate all team members on safe handling of dangerous materials. Ensure a safety observer oversees all handling of said materials.	Safety emphasized before each evolution.
Injury from Power Equipment	1	Poor safety practices, lack of knowledge about dangers involved with the power equipment.	Could cause severe injury to crucial team members, thus placing more workload on other members, decreasing the overall quality of the output of their work.	Educate and train all team members on safe operation of dangerous equipment. Ensure a safety observer oversees all handling of said equipment.	Proper safety measures taken.
Motor or black powder explosion	1	Variety of potential causes, ranging from unavoidable accidents to user error.	Could delay project progress, could cause project to fail if it happens at a crucial time during the end or at the competition. Could force redesign.	Educate and train all team members on safe handling of motors and black powder. Ensure a safety observer oversees all handling of all motors and black powder.	Proper training provided and only handled under supervision.

5.2.5 Environmental Concerns

Navy Rockets understands the impact of the environment when it deals with high power rocketry. The rocket motors create ejection gases as the motor launches the rocket. These gases are directed downwards during takeoff into the ground. However, a blast plate will be used to deflect the gas from entering directly into the ground. All spent motors will be disposed of properly.

The environment also causes concerns to the rocket as well. The humidity and temperature of the air can affect the way the motor functions. If the motor is exposed to poor conditions it will not launch as expected. This will be mitigated by keeping the motors in the proper conditions and ensuring they are not launched if anything is found to be wrong. The complete analysis can be found in Table 23 and 24. The analysis scores the hazards using the ORM system.

Table 23. Environmental Impact on the Rocket

Hazard	ORM Value	Cause	Effect	Mitigation	Verification
Environmental Concerns					
Environmental Impact on the Rocket					
High temperature	2	Environmental causes	Could alter performance of rocket engine; cause components to overheat	Monitor weather forecast; establish cutoff temperature	Monitored forecast.
High humidity	2	Environmental causes	Could decrease performance of rocket engine due to density of air	Monitor weather forecast; be aware of potential harmful effects of humidity	Monitored forecast.
Very low temperature	2	Environmental causes	Could alter performance of rocket engine; cause components to freeze	Monitor weather forecast; establish cutoff temperature	Monitored forecast.

High winds	4	Pressure differentials of Earth's atmosphere.	Delay launch, scrub launch, make rocket fly out of recoverable range, make rocket crash, knock rocket over on stand.	Monitor wind conditions prior to launch, establish a hard cutoff wind limit that will delay a launch. Always be aware of wind direction and velocity for recovery purposes.	Monitored forecast.
Fog	4	Water vapor condenses at dew point temperature.	Delay launch, scrub launch, make it difficult to track rocket in the air after launch.	Monitor fog conditions prior to launch, as well as predicted conditions during the window of flight time. If fog will causes an issue, delay or scrub the launch.	Monitored forecast.

Table 24. Rocket Impact on the Environment

Hazard	ORM Value	Cause	Effect	Mitigation	Verification
Rocket Impact on the Environment					
Harming animals	4	Rocket material falling directly onto or in such a way that it effects wildlife or plant species	Be aware of wind direction and possible drift range of rocket under parachute	Do not launch if the potential for harming wildlife or plants exists; research the local wildlife	Launched clear of sensitive locations
Chemicals leaking into the ground	4	Faulty seals, poor handling of materials	Could expose harmful chemicals to the environment.	Be cautious in handling of materials, ensure components are properly sealed.	Materials handled carefully.
Motor fire	2	Overheating, poor firing sequence	Rocket won't launch; burns could harm rocket structure	Ensure ignition sequence occurs properly, do not operate in excessive heat situations	No motor fire occurred; still taking proper precautions.
Mid-air explosion	2	Various causes	Parachute won't deploy, rocket materials will fall uncontrollably	Test repeatedly to ensure sequences occur properly	
Materials not discarded	3	Materials and trash may be left around the launch site.	Hazard to animals and does not look good for the area.	Check the area for garbage and ensure that all rocket supplies and materials are accounted for after launch.	Proper attention directed toward cleanup efforts

6 Project Plan

6.1 Budget Plan

A comprehensive budget of Navy Rockets' participation in the 2014-2015 Student Launch can be seen below in Table 25. The full scale component of this budget is further detailed in Table 26.

Table 25. Navy Rockets Comprehensive Budget

Expected Costs, 2014-2015	
Full Scale	\$7,786.66
Subscale	\$500.00
Testing and Development	\$600.00
Travel	\$13,152.00
Outreach	\$500.00
Total	\$22,538.66

Table 26. Full-Scale Itemized Budget

Full Scale Itemized Budget				
Subsystem	Item	Unit Cost	Quantity	Total Cost
Rocket Structure	11oz 2x2 Twill Weave Carbon Fiber Cloth	\$ 43.50	7	\$ 304.50
	West System 205b Fast Hardener	\$ 33.35	1	\$ 33.35
	West System 105b Epoxy Resin	\$ 82.05	1	\$ 82.05
	Aero-Mat Soric LRC Honeycomb Foam	\$ 21.40	3	\$ 64.20
	10oz E Glass	\$ 6.95	5	\$ 34.75
	G10 FR4 Glass Epoxy Sheet	\$ 26.95	1	\$ 26.95
	Nylon Shear Pins	\$ 2.95	2	\$ 5.90
Avionics and Recovery	Garmin Astro Bundle (Astro 320 and T5 Device)	\$ 599.99	1	\$ 599.99
	Garmin T5 Device	\$ 249.99	1	\$ 249.99
	Large Capacity Ejection Canisters	\$ 12.50	1	\$ 12.50
	Snap Action Switch	\$ 2.70	5	\$ 13.50
	StratoLoggerCF Altimeter	\$ 49.46	2	\$ 98.92
	Fruity Chutes Iris Ultra 72" Parachute	\$ 201.16	1	\$ 201.16
	Fruity Chutes Iris Ultra 60" Parachute	\$ 166.92	1	\$ 166.92
	Fruity Chutes 24" Classic Elliptical Parachute	\$ 62.06	1	\$ 62.06
	18" Chute Protector	\$ 9.99	2	\$ 19.98
	9/16" Tubular White Nylon	\$ 1.15	20	\$ 23.00
	Black Diamond Positron Screwgate Carabiner	\$ 9.95	10	\$ 99.50
	Eyebolt	\$ 1.56	6	\$ 9.36
Payload Bay	Hitec HS-422 Servo Motor	\$ 9.99	1	\$ 9.99
	Arduino Micro Microcontroller	\$ 23.95	1	\$ 23.95
	12V Battery	\$ 9.95	1	\$ 9.95
	1/4" Threaded Steel Rod	\$ 7.96	1	\$ 7.96
	MaxStream xBee-Pro 900HP Wireless Serial Modem	\$ 39.00	1	\$ 39.00
	Accuride 3832C Full Extension Slide, 8"	\$ 15.33	0.5	\$ 7.67
	11.935" Aluminum Beam	\$ 7.99	1	\$ 7.99
	32P Beam Gear Rack	\$ 5.99	1	\$ 5.99
	Beam Bracket S, Pair	\$ 1.49	1	\$ 1.49
	Beam Attachment Block B	\$ 4.99	1	\$ 4.99
	1.50" Aluminum Channel	\$ 2.99	1	\$ 2.99
	16 Tooth, 32 Pitch, 4mm Bore Pinion Gear	\$ 7.99	1	\$ 7.99
	6-32 Nylock Nuts	\$ 1.59	1	\$ 1.59
	#6 Washers	\$ 0.89	1	\$ 0.89
	Actobotics 32 RPM Precision Planetary Gearmotor	\$ 27.99	1	\$ 27.99
	Planetary Gearmotor Mount A	\$ 4.99	1	\$ 4.99
	0.625" L x 6-32 Zinc-Plated Alloy Steel Socket Head Cap Screw	\$ 2.59	1	\$ 2.59
AGSE	Scorbot-ER V	\$ 2,000.00	1	\$ 2,000.00
	Lenovo ThinkPad 11e	\$ 505.55	1	\$ 505.55
	Aluminum Square Tubing, 2"x2"x1/8"	\$ 85.00	4	\$ 340.00
	Aluminum Round Tubing, 1"Dia	\$ 32.00	1	\$ 32.00
	Aluminum Stock and Plating	\$ 150.00	1	\$ 150.00
	Steel Spur Gear, 20 Pitch, 15 Teeth	\$ 18.53	1	\$ 18.53
	Roller Chain (ANSI Number 35, 3/8" Pitch), 20ft length	\$ 78.00	2	\$ 156.00
	Roller Chain (ANSI Number 35, 3/8" Pitch), 10ft length	\$ 39.00	4	\$ 156.00
	Roller Chain Attachment Link Tab Syle for ANSI #35 Chain	\$ 2.66	4	\$ 10.64
	Connecting Link for ANSI #35 Chain	\$ 7.00	0.82	\$ 5.74
	T-Handle Push Button Quick Release Pin (3/16" x 2")	\$ 19.16	4	\$ 76.64
	T-Handle Push Button Quick Release Pin (3/16" x 2-1/4")	\$ 19.18	4	\$ 76.72
	Steel Machinable Bore Sprocket for ANSI #35 Roller Chain	\$ 44.45	6	\$ 266.70
	Rubber Wheel (4" Diameter)	\$ 6.57	1	\$ 6.57
	Steel Flange Mounted Ball Bearing (1" Shaft Diameter)	\$ 37.62	4	\$ 150.48
	Aluminum Channel 6063 (2x1x1/8"), 16 ft	\$ 30.00	2	\$ 60.00
	Firgelli Automations Light Duty Rod Actuator - 150lb/24"	\$ 119.99	1	\$ 119.99
	Power-Sonic 12V 75AH Battery	\$ 129.99	1	\$ 129.99
	Roboteq SDC1130 Brushed DC Motor Controller	\$ 125.00	1	\$ 125.00
	NPC T74 Electric Motor	\$ 355.00	1	\$ 355.00
	MaxStream xBee-Pro 900HP Wireless Serial Modem	\$ 39.00	4	\$ 156.00
Propulsion	Cesaroni K1200 54mm Motor	\$ 138.00	1	\$ 138.00
	Cesaroni 54mm 5 Grain Case	\$ 97.64	1	\$ 97.64
	Tube-Fabric, 2.125"x2.253"x72"	\$ 259.99	0.33	\$ 85.80
	Pro 54 Rear Closure (P54-CL)	\$ 40.00	1	\$ 40.00
	Retainer 54mm Flanged (AP54)	\$ 40.00	1	\$ 40.00
Launch Vehicle Total				\$ 2,678.02
AGSE Total				\$ 4,897.55
TOTAL				\$ 7,575.57

6.2 Funding Plan

For the 2014-2015 Student Launch competition, Navy Rockets has received funding from the Defense Advanced Research Projects Agency (DARPA). There is also potential for additional funding from the USNA MSTEM program, but this funding is currently non-finalized. Table 27 below details Navy Rockets' funding plan.

Table 27. Navy Rockets' Funding Plan

Navy Rockets SL Funding, 2014-2015	
DARPA	\$40,000.00
USNA MSTEM*	\$5,000.00
Total	\$45,000.00
*Denotes a non-finalized source.	

Navy Rockets expected funding results in over a \$17,000 margin over the budgeted project costs. This margin will allow Navy Rockets to successfully compete in the 2014-2015 Student Launch, even if the projections of project costs are exceeded.

6.3 Timeline

In order for Navy Rockets to stay on track, a schedule has been created. This Gantt chart, found in Appendix G, shows the progress and plans for the team until launch. The Navy Rockets' milestone schedule for the project is shown in Table 28.

Table 28. Milestone Schedule

Date	Milestone Event
Nov. 05	Design Concept Sub Scale Model Completed
Nov. 08	Successful Flight – Body Design Validated
Nov. 19	½ Sub Scale Model Completed
Nov. 14	PDR Presentation
Nov. 30	SCORBOT Initial Programming Complete
Dec. 01	GPS, Recovery Components, Avionics, I242 Motor Received
Dec. 06	Recovery Systems Test Flight Scrubbed (Weather)
Dec. 10	Rocket Body Mold Design Finished
Jan. 08	Wind Tunnel Test Model Fabrication Begins
Jan. 12	SCORBOT/Payload Test Bed Complete
Jan. 14	CDR Mock Presentation with Faculty
Jan. 15	CDR Completed and Submitted
Jan. 25	Subscale Launches Successful
Mar. 05	Launch Vehicle for Testing Complete
Mar. 07	Full Scale Launch Successful
Mar. 11	Payload Section Complete
Mar. 13	FRR Completed and Submitted

In order to ensure rocket and AGSE completion a project punch list has been created, shown in Table 28. This punch list is a list of the final jobs that must be completed before the competition.

Table 29. Project Punch List

Completion Date	Item
Alex – Avionics	
23 Mar	Install new low drag switches and LEDs
25 Mar	Receive USB cord
25 Mar	Reprogram deployment altitudes
Cole – Rocket Body	
23 Mar	Create organization and securement for avionics boards
23 Mar	Test shear pin strength for final configuration
25 Mar	Integrate nose cone with payload bay
27 Mar	Balance rocket weight with predicted values
29 Mar	Sand and paint rocket
Thor – Payload Bay	
22 Mar	Mount all components on mockup
23 Mar	Mockup testing
24 Mar	Complete Arduino Code
25 Mar	Integrate nosecone with payload bay
27 Mar	Full scale testing
Richie - AGSE	
25 Mar	Complete tower and sled
25 Mar	Construct Scorbot Plate
25 Mar	Integrate Igniter insertion unit to sled
26 Mar	Attach motor to tower
26 Mar	Attach gate latches
26 Mar	Setup safety lights
26 Mar	Connect all systems to power
27 Mar	Integrate wireless communication
27 Mar	Full system test
Sam - Coding	
25 Mar	Scorbot calibrated
25 Mar	Igniter insertion calibrated
25 Mar	Tower motor calibrated
27 Mar	Wireless integration of AGSE and laptop
27 Mar	Full wireless system test
Andy – Igniter Insertion	
25 Mar	Calibrate actuator
26 Mar	Integrate actuator to AGSE
26 Mar	Connect to main power source
27 Mar	Full system test

The team also plans on completing another full scale launch and competition test on 28 March 2015. This launch will integrate the AGSE system and launch the rocket with the payload section. The goal is to simulate the competition and determine if anything needs changed before reporting to the Student Launch. The team will focus on the time constraints and simulate the competition launching environment.

6.4 Educational Engagement

Navy Rockets intends to involve itself in the community through educational outreach events. The main targets of outreach events will be primary and secondary school students interested in the areas of Science, Technology, and Mathematics (STEM). In general, Navy Rockets participation in the outreach events will be supplementary to the overall goal of the event. All STEM events involve the rotation of interested young scholars through a myriad of engineering and technological disciplines. Navy Rockets plans to provide an opportunity for under-represented populations to experience design and engineering processes. This is to be done outside of a classroom setting through selected STEM events where participants engaged and actively participating.

6.4.1 STEM Coordination

According to the USNA STEM website, the outreach methodology is to “utilize unique approach to recruiting and retaining technologists by actively engaging elementary/middle/high school students and teachers in a wide variety of science and engineering events (camps, mini-camps, competitions, site visits, short courses, internships) to initiate interest and enthusiasm for future STEM participation in academic and career choices. Unique approach is defined by project based, Navy-relevant curriculum, focusing on current topics, and a pyramidal structure with practicing Navy technologists/educators on top and near peer midshipmen acting as the interface with students, using the outstanding USNA resources as a backdrop for the activities.

Navy Rockets will supplement the mission of the STEM Program by fulfilling its own requirements. The shared goals of the USNA STEM program and Navy Rockets are:

- Outreach with local communities to influence students and teachers to increase focus toward STEM-related studies and activities.
- Allow Navy Rocket participants to be intellectually challenged by creating programs for Midshipmen, and other program participants that will facilitate problem solving and critical thinking while still developing a basic technical sense of the projects.

- Create an interest in aerospace specifically, and all aspects of systems engineering that it entails. Through hands on utilization of technology and computer programs, Navy Rockets hopes to foster interest in the future of aerospace engineering and space flight.

6.4.2 Team Participation

It is of utmost importance that each active member of Navy Rockets participates in outreach such that they have direct educational interaction with at least 100 different participants. This will ensure that the Student Launch minimum requirement of 200 participants, at least 100 being middle school, is surpassed.

6.4.3 STEM events

Navy Rockets plans to be involved in unique STEM events where different populations are targeted. There are four types of events that Navy Rockets plans on doing. All four events involve direct interaction with the participants. The four types are

- Direct Educational interaction involving Aerospace Engineering
- Direct Outreach interaction involving aerospace engineering
- Direct Educational interaction not involving aerospace engineering
- Direct Outreach interaction not involving aerospace engineering

The four types of events will encompass Navy Rockets' educational outreach. Of that, the events where Navy Rockets is interacting through aerospace engineering topics will be the majority of the events attended by Navy Rockets.

Navy Rockets plans on impacting the following STEM events. The events are not a comprehensive list of the events the team members attend, but they are a list of the major events that are scheduled at the time of the proposal.

6.4.3.1 MESA DAY

Done in collaboration with Maryland Mathematics Engineering Science Achievement (MESA), MESA day is one of the primary recurring USNA STEM events that Navy Rockets plans on doing. MESA day is a full day of involved activities that keep elementary students from local counties and Baltimore City involved and interested in STEM related activities. Along with a plethora of age-appropriate interactive activities in different STEM areas, groups are encouraged to participate in a mini engineering design competition. Navy Rockets' involvement in MESA day would consist of creating aerospace specific activities that will keep the students engaged and attentive. MESA day occurs monthly.

6.4.3.2 Mini-STEM

At the Naval Academy, high schools from around the country have students come visit USNA for an overnight visit or a long weekend. This is known as a Candidate Visit Weekend. During these candidate visits, the students tour the technical majors, but more importantly, spend time engaged in interactive science and engineering activities. Navy Rockets plans to bolster the candidate's visits with helpful science and engineering activities. Navy Rockets has the ability to conduct wind tunnel experiments, load cell experiments, and much more with the mini-STEM groups. Candidate visits are held a handful of times during a semester, so there are an abundance of mini-STEM opportunities for Navy Rockets to pick up on.

6.4.3.3 Girls-Only STEM Day

Part of the Girls Exploring Technology through Innovative Topics (GET IT and go) Program, the girls-only STEM day focuses on engineering design and development through a comprehensive competition. The goal is to encourage female participation in STEM programs and studies because females are under-represented in STEM communities. At the competition, female students will have the opportunity to compete, and to attend workshops and meet female faculty members working on innovative technologies, and sciences. The girls-only STEM day is a one-time competition of the GET IT and GO Program.

6.4.3.4 Space Exploration Merit Badge

In conjunction with the National Eagle Scout Association (NESA) chapter at the Naval Academy, Navy Rockets will counsel groups of Boy Scouts to achieve the Space Exploration Merit Badge on Martin Luther King weekend in January of 2015. The merit badge involves instruction about Newton's Laws, model rocketry, and much more. The complete requirements for the badge can be found on the Boy Scouts of America's (BSA) website.

6.4.4 Sustainability

Because it is the first year in the competition for Navy Rockets, extra measures will be taken in order to sustain the project for years to come. While it is difficult for Navy Rockets to receive funding through commercial enterprises and other businesses, the team is continually lobbying for community support in other areas. Outside of the Student Launch Initiative, the Navy Rockets club is able to get continued funding and support through the USNA STEM program. Other than that, Navy Rockets has had a mutually beneficial relationship with the local AIAA student chapter, and the local amateur rocket associations. Similar to the Student Launch Initiative, the local programs ask us to perform community outreach on their behalf. Through outreach, Navy Rockets is promoted, along with promoting an interest in pertinent aerospace engineering communities and technological advances.

The Navy Rockets team expends a lot of effort to ensure sustainability and interest in Navy Rockets. Navy Rockets has attended multiple class meetings to promote rocketry, mostly on an amateur level. For example, for the last few years, members have attended aerospace open houses geared toward freshmen. At these open houses, Navy Rockets has a booth, and hands out flyers with information about the team. Aside from that, Navy Rockets attends aerospace specific class-wide pre-registration briefs. At these briefs, classes are told about the classes they can register for in the oncoming semester. Information about Navy Rockets and what the team does is also promulgated at these briefs.

6.4.4.1 Major Sustainability Challenges and Solutions

The major foreseeable challenge for Navy Rockets is team sustainability in the future. It has the possibility of being difficult to find enough interest for future years to come. Because all 4th year students on the team will not be able to be with the team next year there will be a high turnover rate. If there are not enough incoming third and second year students this could pose a problem. Adding to that, the Naval Academy is a smaller school, with a relatively small selection of students pursuing aerospace engineering.

The best solution to this challenge will be to make team information flyers and events more effective in providing interest. A way to do this will be to branch outside of the aerospace engineering department when soliciting for members. The major members of the team now are all aerospace majors. In the future this will most likely not be the case with increased solicitation to, and interest from, other engineering majors.

6.4.5 *Educational Engagement Progress (Proposal to CDR)*

The educational engagement events have progressed as expected following Navy Rocket's admission into the Student Launch competition. Between the submission of the proposal and the admission into the competition, Navy Rockets members conducted educational outreach with a community elementary school through the American Institute of Aeronautics and Astronautics (AIAA). Although the educational outreach did not count towards requirements that NASA has made, the outreach was both beneficial for the participants and the Navy Rockets team members.

Navy Rockets has taken a major part in outreach with the Girls STEM Day at the Naval Academy. With an effect on over 270 participants, Navy Rockets was able to positively influence middle school participants. After submitting the Preliminary Design Review, Navy Rockets started interacting with the community through educational platforms. Navy Rockets proudly shared a role in shaping the minds of young students that attended MESA Day.

6.4.6 Outreach Update

Since the submission of the CDR, Navy Rockets has led 40 boy scouts through the process of obtaining Space Exploration Merit Badges. This outreach event involved scouts learning about NASA missions, astronauts, and most importantly, NASA rockets. The members of Navy Rockets had an excellent time sharing their passion for rocketry and learning with the young boy scouts. Originally, it was written in the proposal that Navy Rockets would go beyond the requirements for the project, and make each member perform direct outreach with a certain amount of people. However, as building has intensified, all hands on the project have been asked to focus on other areas. Because the NASA requirement for the outreach has been reached, further educational engagement will only be supplementary, and only focused on if group members feel that they have extra time.

7 Conclusion

Navy Rockets will produce an autonomous system that will move a soil sample into a high powered launch vehicle. The system will then seal the rocket and erect itself to five degrees from vertical. After the rocket is erected, an igniter will be placed inside the motor and launched to an altitude of 3000 feet. After apogee the system will deploy a parachute and slow the vehicle down as it approaches a target altitude of 1000 feet. At the target altitude the soil sample and payload section will be ejected from the main launch vehicle, deploy a parachute, and return to the Earth without damage.

APPENDIX A: FRR Flysheet

Milestone Review Flysheet					
Institution			Milestone		
United States Naval Academy			Flight Readiness Review		
Vehicle Properties					
Total Length (in)		108			
Diameter (in)		5			
Gross Lift Off Weight (lb.)		27.7			
Airframe Material		Carbon Fiber/ Fiberglass			
Fin Material		G10 Glass Epoxy			
Drag		0.49			
Motor Properties					
Motor Manufacturer(s)		Cesaroni Technology Inc.			
Motor Designation(s)		K1200 White Thunder			
Max/Average Thrust (lb.)		306.6/269.1			
Total Impulse (lb.-sec)		432.8			
Mass (before, after burn)		3.6/1.48			
Liftoff Thrust (lb.)		293.3			
Stability Analysis					
Center of Pressure (in from nose)		80.2			
Center of Gravity (in from nose)		59.8			
Static Stability Margin		4.1 calibers			
Thrust-to-Weight Ratio		10.6			
Rail Size (in)/ Length (in)		0.3/120			
Rail Exit Velocity (ft/s)		77.4			
Ascent Analysis					
Maximum Velocity (ft./s)		484			
Maximum Mach Number		0.44			
Maximum Acceleration (ft./s ²)		326			
Target Apogee (1st Stage if Multiple Stages)		3100			
Stable Velocity (ft/s)		61.7			
Distance to Stable Velocity (ft)		6			
Recovery System Properties					
Drogue Parachute					
Manufacturer/Model		Fruity Chutes			
Size		24 inches			
Altitude at Deployment (ft)		3100			
Velocity at Deployment (ft/s)		10			
Terminal Velocity (ft/s)		62.97			
Recovery Harness Material		Tubular Nylon			
Harness Size/Thickness (in)		9/16			
Recovery Harness Length (ft)		20			
Harness/Airframe Interfaces		Two steel eyebolts, two feet of tubular nylon, Black Diamond Positron Carabineers, and one 500 pound test barrel swivel			
Kinetic Energy of Each Section (ft-lbs)	Section 1	Section 2	Section 3	Section 4	
	1885				
Recovery System Properties					
Main Parachute					
Manufacturer/Model		Fruity Chutes			
Size		72 inch/60 inch			
Altitude at Deployment (ft)		1000			
Velocity at Deployment (ft/s)		62.97			
Terminal Velocity (ft/s)		17.69 / 20.39			
Recovery Harness Material		Tubular Nylon			
Harness Size/Thickness (in)		9/16"			
Recovery Harness Length (ft)		15/10			
Harness/Airframe Interfaces		Single eyebolts, Black Diamond Positron Carabineers, two feet of tubular nylon, 500 lb test barrel swivel			
Kinetic Energy of Each Section (ft-lbs)	Section 1	Section 2	Section 3	Section 4	
	47.94	36.34			
Recovery Electronics					
Altimeter(s)/Timer(s) (Make/Model)		2 PerfectFlite Stratologgers			
Redundancy Plan		The Stratologgers will be both connected to the black powder charge and have their own switch to ensure they operate properly. Each one will be set to spark the charge in case the other fails.			
Pad Stay Time (Launch Configuration)		3 hours			
Recovery Electronics					
Rocket Locators (Make/Model)		Garmin Astro and T3 Dog Device			
Transmitting Frequencies		MURS Frequency			
Black Powder Mass Drogue Chute (grams)		3.25			
Black Powder Mass Main Chute (grams)		2.75			

Milestone Review Flysheet

Institution	United States Naval Academy	Milestone	Flight Readiness Review
--------------------	-----------------------------	------------------	-------------------------

Autonomous Ground Support Equipment (AGSE)			
Capture Mechanism	Overview		
	The Scorbot ER-V is capable of using six different motions to complete the assigned task. These motions are base rotation, shoulder rotation, elbow rotation, wrist pitch, wrist roll, and gripper open/close. The base has a rotation angle of 310 degrees, the shoulder has a rotation angle of $\pm 130^\circ / -35^\circ$ degrees, and elbow has a rotation angle of 130 degrees. The wrist can rotate up within 130 degrees and the wrist can roll within 570 degrees. The gripper will sense when it has grasped an object by means of a gripper sensor integrated into the system. The maximum payload that the Scorbot is rated for is 2.2 lbs. including the mass of the gripper. The Scorbot is capable of operating within a temperature range of 36 to 104 degrees Fahrenheit.		
Container Mechanism	Overview		
	The Scorbot component of the AGSE will place the payload sample into a payload-holding bed within the payload section of the rocket body. This payload bed will be a half-cylinder made of steel. Once the payload is placed within the bed, a servomotor, mounted adjacent to the bed, will rotate a securement tab, so its final position is perpendicular to the longitudinal axis of the bed. This tab will securely hold the payload sample in the bed during erection and flight.		
Launch Rail Mechanism	Overview		
	A motor will raise the rocket sled and four separate gate latches will latch onto the top and bottom of the launch sled when it reaches its launch position, thus keeping it place.		
Igniter Installation Mechanism	Overview		
	The igniter installation mechanism will be mounted on a flat plate at the base of the rocket sled. It will consist of a linear actuator, to which will be affixed a flat, circular steel plate and a thin steel tube. The linear actuator and thin steel tube will both be aligned with the centerline of the rocket motor. The thin steel tube will have the ignition wire run into it and the igniter will stick out just beyond the end of the tube. The tube will be initially located a short distance, along the longitudinal axis of the rocket, away from the motor. The linear actuator will then move the igniter up into its final ignition position within the motor.		
CG Location of Launch Pad (in inches) When Rail is Horizontal (Use Base of Rail as the Reference Point)			21
Moment Analysis	An initial moment analysis of the tower structure in the launch configuration placed the center of gravity at approximately 40 inches above ground level. This indicates that a point force of approximately 33 lbs at the top of the structure is required for the structure to begin to tip along the plane perpendicular to the sled wheel track. Further analysis will be done during the build and testing stages of project.		

Payload	
Payload 1	Overview
	The payload is defined by the NASA Student Launch requirements. The payload bay of the rocket will autonomously secure the payload sample once it is received from the AGSE. It will then seal the nosecone of the rocket to the rocket body.
Payload 2	Overview

Test Plans, Status, and Results	
Ejection Charge Tests	Testing will be done to ensure the calculated black powder charge will actually pressurize the rocket correctly so that the parachutes deploy. Ground testing will entail a static firing of a 1:1 size test section at MDRA's launch facility. --TESTING COMPLETE AND SUCCESSFUL
Sub-scale Test Flights	Sub-scale rockets will be launched with scaled payloads, weight, and motor size. By analyzing the stability of the rocket through inspection, the stability parameters, such as the center of pressure and the center of gravity as ratios of the total rocket length, will be critiqued. The normalized parameter were calculated to be similar to that of the full-scale in order to analyze the stability. --TESTING COMPLETE AND SUCCESSFUL
Full-scale Test Flights	Full-scale testing will entail complete execution of the mission parameters set forth by the Student Launch Instruction. All sub-systems will be tested, to include autonomous insertion of the payload by the AGSE and the ejection of the payload at 1000 feet. Deliverables include confirmation of altitude and stability predictions, ejection charge calculations, and parachute drift calculations. --TESTING COMPLETE AND SUCCESSFUL

APPENDIX B: Component Sizing

Parts Detail

Sustainer

	Nose cone	Fiberglass (1.85 g/cm ³)	Ogive	Len: 25 in	Mass: 1.35 lb
	Payload Section Avonics		Dia _{out} 2 in		Mass: 1.5 lb
	Bulkhead	PVC (1.50 g/cm ³)	Dia _{out} 4.843 in	Len: 0.125 in	Mass: 0.116 lb
	Payload	Fiberglass (1.85 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 5 in	Len: 10 in	Mass: 1.6 lb
	Payload section		Dia _{out} 1.5 in		Mass: 1.75 lb
	Payload Moving Systems		Dia _{out} 4.25 in		Mass: 2 lb
	Bulkhead	Fiberglass (1.85 g/cm ³)	Dia _{out} 4.843 in	Len: 0.079 in	Mass: 0.097 lb
	Tube coupler	PVC (1.50 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 4.843 in	Len: 4 in	Mass: 0 lb
	Parachute Section	Fiberglass (1.85 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 5 in	Len: 21 in	Mass: 1.71 lb
	Payload Parachute	Ripstop nylon (87 g/m ²)	Dia _{out} 60 in	Len: 5.5 in	Mass: 0.382 lb
	Shroud Lines	Tubular nylon (14 mm, 9/16 in) (15 g/m)	Lines: 6	Len: 21 in	
	Shock cord	Tubular nylon (14 mm, 9/16 in) (15 g/m)		Len: 120 in	Mass: 0.108 lb
	Body Main Parachute	Ripstop nylon (87 g/m ²)	Dia _{out} 72 in	Len: 5.5 in	Mass: 0.496 lb
	Shroud Lines	Tubular nylon (14 mm, 9/16 in) (15 g/m)	Lines: 6	Len: 20 in	
	Shock cord	Tubular nylon (14 mm, 9/16 in) (15 g/m)		Len: 180 in	Mass: 0.161 lb
	Main Avonics	Fiberglass (1.85 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 5 in	Len: 14.5 in	Mass: 2.4 lb
	Tube coupler	PVC (1.50 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 4.843 in	Len: 6.5 in	Mass: 0 lb
	Electronics		Dia _{out} 3.984 in		Mass: 4.7 lb
	Tube coupler	PVC (1.50 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 4.843 in	Len: 6.5 in	Mass: 0 lb
	Bulkhead	Fiberglass (1.85 g/cm ³)	Dia _{out} 4.843 in	Len: 0.079 in	Mass: 0.097 lb

	Bulkhead	Fiberglass (1.85 g/cm ³)	Dia _{out} 4.843 in	Len: 0.079 in	Mass: 0.097 lb
	Switch	PVC (1.59 g/cm ³)	Dia _{in} 0.1 in Dia _{out} 0.1 in	Len: 0.5 in	Mass: 0 lb
	Motor Section	Carbon fiber (1.78 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 5 in	Len: 37 in	Mass: 3.1 lb
	Motor mount	Carbon fiber (1.78 g/cm ³)	Dia _{in} 2.126 in Dia _{out} 2.165 in	Len: 26 in	Mass: 0.222 lb
	Shock cord	Tubular nylon (14 mm, 9/16 in) (1.8 g/m)		Len: 180 in	Mass: 0.161 lb
	Drogue	Ripstop nylon (87 g/m ²)	Dia _{out} 24 in	Len: 1.5 in	Mass: 0.172 lb
	Shroud Lines	Tubular nylon (14 mm, 9/16 in) (1.8 g/m)	Lines: 6	Len: 24 in	
	Centering ring	PVC (1.59 g/cm ³)	Dia _{in} 2.165 in Dia _{out} 4.843 in	Len: 0.125 in	Mass: 0.092 lb
	Engine block	Carbon fiber (1.78 g/cm ³)	Dia _{in} 4.843 in Dia _{out} 4.843 in	Len: 0.197 in	Mass: 0 lb
	Centering ring	PVC (1.59 g/cm ³)	Dia _{in} 2.165 in Dia _{out} 4.843 in	Len: 0.125 in	Mass: 0.092 lb
	Launch lug	Carbon fiber (1.78 g/cm ³)	Dia _{in} 0.315 in Dia _{out} 0.394 in	Len: 1.181 in	Mass: 0.003 lb
	Launch lug	Carbon fiber (1.78 g/cm ³)	Dia _{in} 0.315 in Dia _{out} 0.394 in	Len: 1.181 in	Mass: 0.003 lb
	Trapezoidal fin set (3)	Fiberglass (1.85 g/cm ³)	Thick: 0.118 in		Mass: 1.44 lb

APPENDIX C: Wind Tunnel Test Plan

USNA ROCKET PROPULSION PROGRAM

FUNCTIONAL TEST PLAN

USNA-TP-R001

20 AUG 2014

Approvals

Project Engineer	Date
------------------	------

RECORD OF CHANGES

REVISION LETTER	DATE	TITLE OR BRIEF DESCRIPTION	ENTERED BY
A	20 SEP 14	Draft	TM
B	9 JAN 14	Draft	TM

Introduction:

This Functional Test Plan describes the procedures used to operate the flow aerodynamic force test being performed on the University Student Launch Initiative (USLI) scale rocket in the Eiffel Wind Tunnel.

Pressure Variation along Rocket: The purpose of this experiment is to test a scale model rocket at an array of incidence angles with varying Reynolds numbers. This test will allow Navy Rockets to determine the aerodynamic forces present on the rocket throughout the flight. Knowledge of the forces during flight will give way to more accurate analysis of rocket flight path trajectory, especially in comparison to rocket trajectory simulation software. This work will be presented to complement the Navy Rocket research and development as a part of the NASA Student Launch competition.

1.1 Philosophy of OPERATIONS

The scale model testing will take place inside the Eiffel Wind Tunnel in Rickover Hall. It will be mounted to the sting balance, with pressure ports located along the nose cone and rocket body. The nose cone and the fin section will be designed in Solid Works and 3D printed to an exact 0.475:1 scale. The pressure ports will be 3D printed into the scale model nose cone, and drilled into the body section. The body section will be made of PVC. The model will be run at varying Reynolds numbers. The incidence angle of the scale model and the free-stream flow will vary between -10 and 10 degrees.

1.2 Participation

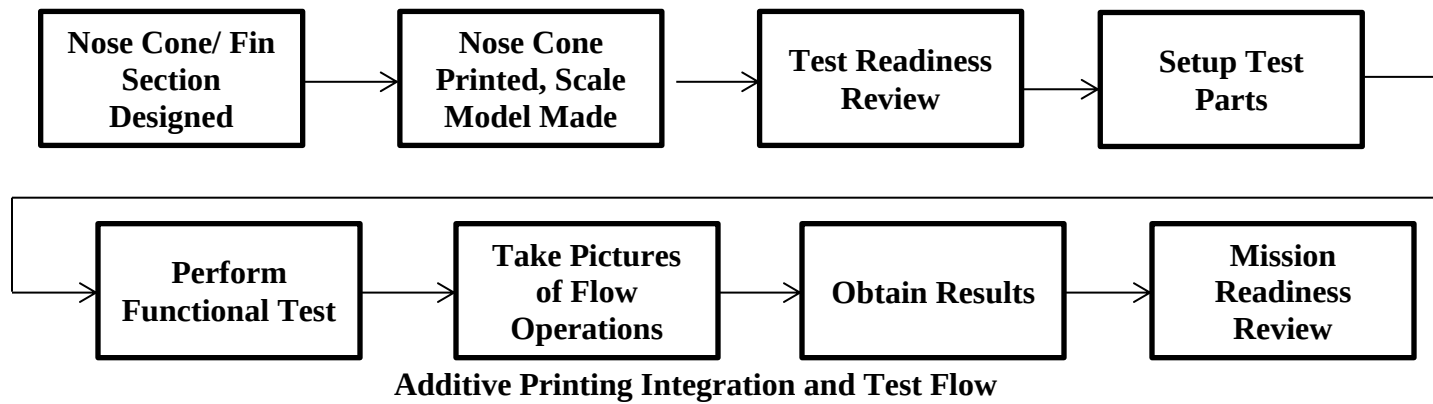
Personnel responsible for the operations are listed in A-1.

C-1. Wind Tunnel Test Personnel

Name	Organization	Role/Responsibility	Contact Information
Captain Kristen Castonguay	USNA Aerospace Engineering Instructor, USAF	Project Manager	410.293.6403 clarkk@usna.edu
Troy McKenzie	USNA Class of 2015	USLI Aerodynamics Lead	m154716@usna.edu

1.3 Flow Diagrams

The Additive Printing integration and test flow is shown below.



2. Injector System Functional Test

2.1 Objectives

The objective of this experiment is to analyze the aerodynamic stability of the rocket used for the NASA Student Launch competition.

2.2 Criteria for Success

The rocket shows static and dynamic stability at all Reynolds numbers tested at. Forces and moments will be taken into account when analyzing stability. The location of the center of pressure (C_p) matches that from simulation software OpenRocket.

2.3 Facilities

The scale model testing will be performed using the Eiffel Wind Tunnel in Rickover hall at USNA.

2.4 Materials

- A. 48.9 in scale model rocket
- B. 64 sections surgical tubing – 1/16 in diameter
- C. 64 stainless steel surgical tubing connectors
- D. 1 Pressure Systems pressure gage cluster – 64 ports

2.5 Test Overview

The test will involve turning the wind tunnel on while all pressure ports are connected.

TEST DATE: _____

TEST PERSON: _____

Initial Rocket Model Test

Step	Description	Comment	Done? (Y/N)	Date	Initial
0	Attach pressure tube to each port on the bottom of the nose cone through the inside of the rocket. Attach tygon tubing through access holes in PVC				
1	Attach scale model aft section to the sting balance.				
2	Run surgical tube through the sting balance attachment out to the pressure gages.				
3	Ensure sting balance is properly				

	attached with the sting balance attachment				
4	Ensure all pressure ports and force measuring devices are securely fitted by inspection, then by flow through test section				
5	Run program at initial test speed.				
6	When flow steadies tabulate data for given speed.				
7	Perform steps 5-6 as needed for each successive test speed at each angle of attack				
8	Once all data is taken, run again at initial test speed				
9	Perform free-stream velocity sweep from initial to final test speeds, simultaneously tabulating data.				
10	When finished tabulating velocity sweep, move wind tunnel test speed down to 0%				
11	Shut down wind tunnel and wind tunnel software				
12	Detach the assembly in reverse order of attachment.				

APPENDIX D: Mission Requirements

Req't #	Requirement	Designated Subsystem
1.1	The vehicle shall deliver the payload to, but not exceeding, an apogee altitude of 3,000 feet above ground level (AGL).	Structures & Propulsion
1.2	The vehicle shall carry one commercially available, barometric altimeter for recording the official altitude used in the competition scoring. The altitude score will account for 10% of the team's overall competition score. Teams will receive the maximum number of altitude points (3,000) by fully reaching the 3,000 feet AGL mark. For every foot of deviation above or below the target altitude, the team will lose 1 altitude point. The team's altitude points will be divided by 3,000 to determine the altitude score for the competition.	Avionics
1.2.1	The official scoring altimeter shall report the official competition altitude via a series of beeps to be checked after the competition flight.	Avionics
1.2.2	Teams may have additional altimeters to control vehicle electronics and payload experiment(s).	Avionics & Recovery
1.2.2.1	At the Launch Readiness Review, a NASA official will mark the altimeter that will be used for the official scoring.	Avionics
1.2.2.2	At the launch field, a NASA official will obtain the altitude by listening to the audible beeps reported by the official competition, marked altimeter.	Avionics
1.2.2.3	At the launch field, to aid in determination of the vehicle's apogee, all audible electronics, except for the official altitude-determining altimeter shall be capable of being turned off.	Avionics
1.2.3	The following circumstances will warrant a score of zero for the altitude portion of the competition:	Avionics
1.2.3.1	The official, marked altimeter is damaged and/or does not report an altitude via a series of beeps after the team's competition flight.	Avionics
1.2.3.2	The team does not report to the NASA official designated to record the altitude with their official, marked altimeter on the day of the launch.	Avionics
1.2.3.3.	The altimeter reports an apogee altitude over 5,000 feet AGL.	Avionics
1.2.3.4	The rocket is not flown at the competition launch site.	All
1.3	The launch vehicle shall be designed to be recoverable and reusable. Reusable is defined as being able to launch again on the same day without repairs or modifications.	Structures & Recovery
1.4	The launch vehicle shall have a maximum of four (4) independent	Structures

	sections. An independent section is defined as a section that is either tethered to the main vehicle or is recovered separately from the main vehicle using its own parachute.	
1.5	The launch vehicle shall be limited to a single stage.	Structures
1.6	The launch vehicle shall be capable of being prepared for flight at the launch site within 2 hours, from the time the Federal Aviation Administration flight waiver opens.	All
1.7	The launch vehicle shall be capable of remaining in launch-ready configuration at the pad for a minimum of 1 hour without losing the functionality of any critical on-board component.	Avionics, Payload, and Recovery
1.8	The launch vehicle shall be capable of being launched by a standard 12 volt direct current firing system. The firing system will be provided by the NASA-designated Range Services Provider.	Propulsion
1.9	The launch vehicle shall use a commercially available solid motor propulsion system using ammonium perchlorate composite propellant (APCP) which is approved and certified by the National Association of Rocketry (NAR), Tripoli Rocketry Association (TRA), and/or the Canadian Association of Rocketry (CAR).	Propulsion
1.9.1	Final motor choices must be made by the Critical Design Review (CDR).	Propulsion
1.9.2	Any motor changes after CDR must be approved by the NASA Range Safety Officer (RSO), and will only be approved if the change is for the sole purpose of increasing the safety margin.	Propulsion
1.10.	The total impulse provided by a launch vehicle shall not exceed 5,120 Newton-seconds (L-class).	Propulsion
1.11	Any team participating in Maxi-MAV will be required to provide an inert or replicated version of their motor matching in both size and weight to their launch day motor. This motor will be used during the LRR to ensure the igniter installer will work with the competition motor on launch day.	Propulsion
1.12	Pressure vessels on the vehicle shall be approved by the RSO and shall meet the following criteria:	Structures
1.12.1	The minimum factor of safety (Burst or Ultimate pressure versus Max Expected Operating Pressure) shall be 4:1 with supporting design documentation included in all milestone reviews.	Structures
1.12.2	The low-cycle fatigue life shall be a minimum of 4:1.	Structures
1.12.3	Each pressure vessel shall include a solenoid pressure relief valve that sees the full pressure of the tank.	Structures
1.12.4	Full pedigree of the tank shall be described, including the application for which the tank was designed, and the history of the tank, including the number of pressure cycles put on the tank, by whom, and when.	Structures

1.13	All teams shall successfully launch and recover a subscale model of their full-scale rocket prior to CDR. The subscale model should resemble and perform as similarly as possible to the full-scale model, however, the full-scale shall not be used as the subscale model.	All
1.14	All teams shall successfully launch and recover their full-scale rocket prior to FRR in its final flight configuration. The rocket flown at FRR must be the same rocket to be flown on launch day. The purpose of the full-scale demonstration flight is to demonstrate the launch vehicle's stability, structural integrity, recovery systems, and the team's ability to prepare the launch vehicle for flight. A successful flight is defined as a launch in which all hardware is functioning properly (i.e. drogue chute at apogee, main chute at a lower altitude, functioning tracking devices, etc.). The following criteria must be met during the full scale demonstration flight:	All
1.1.14.1	The vehicle and recovery system shall have functioned as designed.	Recovery
1.14.2	The payload does not have to be flown during the full-scale test flight. The following requirements still apply:	All
1.14.2.1	If the payload is not flown, mass simulators shall be used to simulate the payload mass.	Recovery
1.12.2.2	The mass simulators shall be located in the same approximate location on the rocket as the missing payload mass.	Payload
1.14.2.3	If the payload changes the external surfaces of the rocket (such as with camera housings or external probes) or manages the total energy of the vehicle, those systems shall be active during the full-scale demonstration flight.	Payload
1.14.3	The full-scale motor does not have to be flown during the full-scale test flight. However, it is recommended that the full-scale motor be used to demonstrate full flight readiness and altitude verification. If the full-scale motor is not flown during the full-scale flight, it is desired that the motor simulate, as closely as possible, the predicted maximum velocity and maximum acceleration of the competition flight.	Payload
1.14.4	The vehicle shall be flown in its fully ballasted configuration during the full-scale test flight. Fully ballasted refers to the same amount of ballast that will be flown during the competition flight.	All
1.14.5	After successfully completing the full-scale demonstration flight, the launch vehicle or any of its components shall not be modified without the concurrence of the NASA Range Safety Officer (RSO).	All
1.15	Each team will have a maximum budget they may spend on the rocket and the Autonomous Ground Support Equipment (AGSE).	All

	Teams who are participating in the Maxi-MAV competition are limited to a \$10,000 budget while teams participating in Mini-MAV are limited to \$5,000. The cost is for the competition rocket and AGSE as it sits on the pad, including all purchased components. The fair market value of all donated items or materials shall be included in the cost analysis. The following items may be omitted from the total cost of the vehicle:	
1.16	Vehicle Prohibitions	
1.16.1	The launch vehicle shall not utilize forward canards.	Structures
1.16.2	The launch vehicle shall not utilize forward firing motors.	Propulsion
1.16.3	The launch vehicle shall not utilize motors that expel titanium sponges (Sparky, Skidmark, Metal Storm, etc.).	Propulsion
1.16.4	The launch vehicle shall not utilize hybrid motors.	Propulsion
1.16.5	The launch vehicle shall not utilize a cluster of motors.	Propulsion
2.1	The launch vehicle shall stage the deployment of its recovery devices, where a drogue parachute is deployed at apogee and a main parachute is deployed at a much lower altitude. Tumble recovery or streamer recovery from apogee to main parachute deployment is also permissible, provided the kinetic energy during drogue-stage descent is reasonable, as deemed by the Range Safety Officer.	Recovery
2.2.	Teams must perform a successful ground ejection test for both the drogue and main parachutes. This must be done prior to the initial subscale and full scale launches.	Recovery
2.3	At landing, each independent section of the launch vehicle shall have a maximum kinetic energy of 75 ft.-lbf.	Recovery
2.4	The recovery system electrical circuits shall be completely independent of any payload electrical circuits.	Recovery
2.5	The recovery system shall contain redundant, commercially available altimeters. The term “altimeters” includes both simple altimeters and more sophisticated flight computers. One of these altimeters may be chosen as the competition altimeter.	Recovery
2.6	A dedicated arming switch shall arm each altimeter, which is accessible from the exterior of the rocket airframe when the rocket is in the launch configuration on the launch pad.	Recovery
2.7	Each altimeter shall have a dedicated power supply.	Recovery
2.8	Each arming switch shall be capable of being locked in the ON position for launch.	Recovery
2.9	Removable shear pins shall be used for both the main parachute compartment and the drogue parachute compartment.	Recovery
2.10.	An electronic tracking device shall be installed in the launch vehicle and shall transmit the position of the tethered vehicle or any independent section to a ground receiver.	Avionics

2.10.1	Any rocket section, or payload component, which lands untethered to the launch vehicle shall also carry an active electronic tracking device.	Avionics
2.10.2	The electronic tracking device shall be fully functional during the official flight at the competition launch site.	Avionics
2.11	The recovery system electronics shall not be adversely affected by any other on-board electronic devices during flight (from launch until landing).	Recovery
2.11.1	The recovery system altimeters shall be physically located in a separate compartment within the vehicle from any other radio frequency transmitting device and/or magnetic wave producing device.	Recovery
2.11.2	The recovery system electronics shall be shielded from all onboard transmitting devices, to avoid inadvertent excitation of the recovery system electronics.	Recovery
2.11.3	The recovery system electronics shall be shielded from all onboard devices which may generate magnetic waves (such as generators, solenoid valves, and Tesla coils) to avoid inadvertent excitation of the recovery system.	Recovery
2.11.4	The recovery system electronics shall be shielded from any other onboard devices which may adversely affect the proper operation of the recovery system electronics.	Recovery
3.2.1.12	The rocket will launch as designed and jettison the payload at 1,000 feet AGL during descent	Payload & Recovery
3.2.4.1	Each launch vehicle must have the space to contain a cylindrical payload approximately 3/4 inch in diameter and 4.75 inches in length. The payload will be made of 3/4 x 3 inch PVC tubing filled with sand and weighing approximately 4 oz., and capped with domed PVC end caps. Each launch vehicle must be able to seal the payload containment area autonomously prior to launch.	Payload
3.2.4.2	Teams may construct their own payload according to the above specifications, however, each team will be required to use a regulation payload provided to them on launch day.	Payload
3.2.4.3	The payload will not contain any hooks or other means to grab it. A diagram of the payload and a sample payload will be provided to each team at time of acceptance into the competition.	Payload
3.2.4.4	The payload may be placed anywhere in the launch area for insertion, as long as it is outside the mold line of the launch vehicle when placed in the horizontal position on the AGSE.	Payload
3.2.4.5	The payload container must utilize a parachute for recovery and contain a GPS or radio locator.	Avionics, Payload, & Recovery

Req't #	Designated Subsystem	Verification
1.1	Structures & Propulsion	Analysis & Testing
1.2	Avionics	Design
1.2.1	Avionics	Design
1.2.2	Avionics & Recovery	Design
1.2.2.1	Avionics	-
1.2.2.2	Avionics	Design
1.2.2.3	Avionics	-
1.2.3	Avionics	Testing
1.2.3.1	Avionics	Testing
1.2.3.2	Avionics	Testing
1.2.3.3.	Avionics	Testing
1.2.3.4	All	Testing
1.3	Structures & Recovery	Testing
1.4	Structures	Design
1.5	Structures	Design
1.6	All	Design
1.7	Avionics, Payload, and Recovery	Design
1.8	Propulsion	Design
1.9	Propulsion	Design
1.9.1	Propulsion	Design
1.9.2	Propulsion	Design
1.10.	Propulsion	Analysis
1.11	Propulsion	Design
1.12	Structures	-
1.12.1	Structures	Analysis
1.12.2	Structures	Analysis
1.12.3	Structures	Analysis
1.12.4	Structures	Analysis
1.13	All	Testing
1.14	All	Testing
1.1.14.1	Recovery	Analysis and Testing
1.14.2	All	Testing
1.14.2.1	Recovery	Testing
1.12.2.2	Payload	Testing

1.14.2.3	Payload	Testing
1.14.3	Payload	Testing
1.14.4	All	Testing
1.14.5	All	Testing
1.15	All	Design
1.16		-
1.16.1	Structures	Design
1.16.2	Propulsion	Design
1.16.3	Propulsion	Design
1.16.4	Propulsion	Design
1.16.5	Propulsion	Design
2.1	Recovery	Design
2.2.	Recovery	Testing
2.3	Recovery	Analysis
2.4	Recovery	Design
2.5	Recovery	Design
2.6	Recovery	Design
2.7	Recovery	Design
2.8	Recovery	Design
2.9	Recovery	Design
2.10.	Avionics	Design
2.10.1	Avionics	Design
2.10.2	Avionics	Design
2.11	Recovery	Testing
2.11.1	Recovery	Design
2.11.2	Recovery	Testing
2.11.3	Recovery	Testing
2.11.4	Recovery	Testing
3.2.1.12	Payload & Recovery	Testing
3.2.4.1	Payload	Design
3.2.4.2	Payload	Design
3.2.4.3	Payload	Design
3.2.4.4	Payload	Testing
3.2.4.5	Avionics, Payload, & Recovery	Design

APPENDIX E: Laws and Safety Codes

E.1 NAR High Power Rocket Safety Code



NAR High Power Rocket Safety Code

Effective August 2012

1. **Certification.** I will only fly high power rockets or possess high power rocket motors that are within the scope of my user certification and required licensing.
2. **Materials.** I will use only lightweight materials such as paper, wood, rubber, plastic, fiberglass, or when necessary ductile metal, for the construction of my rocket.
3. **Motors.** I will use only certified, commercially made rocket motors, and will not tamper with these motors or use them for any purposes except those recommended by the manufacturer. I will keep smoking, open flames, and heat sources at least 25 feet away from these motors.
4. **Ignition System.** I will launch my rockets with an electrical launch system, and with electrical motor igniters that are installed in the motor only after my rocket is at the launching or prepping area. My launch system will have a safety interlock that is in series with the launch switch that is not installed until my rocket is ready for launch, and will use a launch switch that returns to the "off" position when released. The function of onboard energetics and firing circuits will be inhibited except when my rocket is in the launching position.
5. **Misfires.** If my rocket does not launch when I press the button of my electrical launch system, I will remove the launcher's safety interlock or disconnect its battery, and will wait 60 seconds after the last launch attempt before allowing anyone to approach the rocket.
6. **Launch Safety.** I will use a 5-second countdown before launch. I will ensure that a means is available to warn participants and spectators in the event of a problem. I will ensure that no person is closer to the launch pad than allowed by the accompanying Minimum Distance Table. When arming onboard energetics and firing circuits I will ensure that no person is at the pad except safety personnel and those required for arming and disarming operations. I will check the stability of my rocket before flight and will not fly it if it cannot be determined to be stable. When conducting a simultaneous launch of more than one high power rocket I will observe the additional requirements of NFPA 1127.
7. **Launcher.** I will launch my rocket from a stable device that provides rigid guidance until the rocket has attained a speed that ensures a stable flight, and that is pointed to within 20 degrees of the vertical. If the wind speed exceeds 5 miles per hour I will use a launcher length that permits the rocket to attain a safe velocity before separation from the launcher. I will use a blast deflector to prevent the motor's exhaust from hitting the ground. I will ensure that there is no dry grass within a clear distance of each launch pad determined by the accompanying Minimum Distance table, and will increase this distance by a factor of 1.5 and clear that area of all combustible material if the rocket motor being launched uses titanium sponge in the propellant.

8. **Size.** My rocket will not contain any combination of motors that total more than 40,960 N-sec (9208 pound-seconds) of total impulse. My rocket will not weigh more at liftoff than one-third of the certified average thrust of the high power rocket motor(s) intended to be ignited at launch.
9. **Flight Safety.** I will not launch my rocket at targets, into clouds, near airplanes, or on trajectories that take it directly over the heads of spectators or beyond the boundaries of the launch site, and will not put any flammable or explosive payload in my rocket. I will not launch my rockets if wind speeds exceed 20 miles per hour. I will comply with Federal Aviation Administration airspace regulations when flying, and will ensure that my rocket will not exceed any applicable altitude limit in effect at that launch site.
10. **Launch Site.** I will launch my rocket outdoors, in an open area where trees, power lines, occupied buildings, and persons not involved in the launch do not present a hazard, and that is at least as large on its smallest dimension as one-half of the maximum altitude to which rockets are allowed to be flown at that site or 1500 feet, whichever is greater, or 1000 feet for rockets with a combined total impulse of less than 160 N-sec, a total liftoff weight of less than 1500 grams, and a maximum expected altitude of less than 610 meters (2000 feet).
11. **Launcher Location.** My launcher will be at least one half the minimum launch site dimension, or 1500 feet (whichever is greater) from any occupied building, or from any public highway on which traffic flow exceeds 10 vehicles per hour, not including traffic flow related to the launch. It will also be no closer than the appropriate Minimum Personnel Distance from the accompanying table from any boundary of the launch site.
12. **Recovery System.** I will use a recovery system such as a parachute in my rocket so that all parts of my rocket return safely and undamaged and can be flown again, and I will use only flame-resistant or fireproof recovery system wadding in my rocket.
13. **Recovery Safety.** I will not attempt to recover my rocket from power lines, tall trees, or other dangerous places, fly it under conditions where it may recover in spectator areas or outside the launch site, or attempt to catch it as it approaches the ground.

MINIMUM DISTANCE TABLE				
Installed Total Impulse (N-sec)	Equivalent Motor Type	Minimum Clear Distance (ft.)	Minimum Personnel Distance (ft.)	Minimum Personnel Distance (Complex Rocket) (ft.)
0 - 320.00	H or smaller	50	100	200
320.01 - 640.00	I	50	100	200
640.01 - 1280.00	J	50	100	200
1280.01 - 2560.00	K	75	200	300
2560.01 - 5120.00	L	100	300	500
5120.01 - 10,240.00	M	125	500	1000
10,240.01 - 20,480.00	N	125	1000	1500
20,480.01 - 40,960.00	O	125	1500	2000

Note: A complex rocket is one that is multi-staged or that is propelled by two or more rocket motors

E.2 TRA Code for High Power Rocketry

Code for High Power Rocketry Tripoli Rocketry Association

This High Power Rocketry Safety Code is the product of many years of effort on behalf of the hobby by those who care about it and whose prime interest is safety. It is not a perfect standard, but adequate. This minimum requirement, if followed, will preserve the hobby in a safe environment for all who participate and for spectators. Tripoli's Prefectures and other launch sponsors should be aware that wisdom should dictate what is safe and what is not at each launch site. With this standard as the minimum, it will be your responsibility to regulate your own launches within reason. You should be cautious not to over-restrict the activity. Our members, who sometimes travel great distances to attend launches, will expect this Safety Code to be the standard at Tripoli sanctioned launches.

This version of the safety code will appear much terser than prior versions. This version is intended to *augment* NFPA 1127 Code for High Power Rocketry with codes that are specific to Tripoli. The foundation of the Tripoli High Power Safety Code is NFPA 1127 as that has been adopted by many Authorities Having Jurisdiction and define the minimum set of codes required. Tripoli codes cannot relax NFPA codes; we can only add codes that are intended to increase safety at our sanctioned launches.

General Requirements

1-1 Scope

- 1-1.1** This code shall apply to safe operation of High Power rocket launches. It will also address some aspects of safe rocket design, and construction, as well as limitations of motor power, for use by the certified user for education, recreation and sporting use.

1-2 Purpose

- 1-2.1** The purpose of this code shall be to establish guidelines for reasonably safe operation of high power rocket at Tripoli sanctioned/insured launches; both "commercial" as well as Research (covered in a separate code).

- 1-3 Definitions** For the purposes of this code, the following terms shall be defined as stated in this section. Some of these may be redundant from NFPA 1127.

High Power Rocket Flier (HPR Flier). A TRA member or a member of an approved, insured rocketry organization that is 18 years old or older.

Launch Director (LD): A Level 2 or Level 3 flier who has overall administrative responsibility for the launch.

Named Insured: Individuals that are not Tripoli Members but are members of groups that have been submitted to, and approved by the Tripoli Insurance Liaison.

Participants. Persons that are either:

7/31/2012

- HPR Fliers.
- Model Rocket Fliers.
- Invited Guests of fliers.
- Spectators. General population of non-fliers, and non-invited guests.

Range Safety Officer (RSO). A Level 2 or Level 3 flier whose responsibility and duty during the operation of high power rockets is to confirm a rocket's compliance with the applicable provisions of this code, be confident that the rocket will fly in a safe manner, designate the areas of the launch site, and oversee the safety of all spectators and participants..

Sanctioned Launch. Also called *Insured Launch*. Any launch of a rocket that meets *ALL* of the following constraints:

1. Responsible person of launch shall be member of Tripoli in good standing.
2. Follows the appropriate Tripoli Safety Code.
3. Legal: All AHJ (e.g. FAA waiver) requirements/regulations met and any required permits secured.
4. Landowner permission/constraints.

Shall. Indicates a mandatory requirement.

Should. Indicates a recommendation or that which is advised but not required.

Spectator. A nonparticipant whose primary purpose is to view a high power rocket launch.

Spectator Area. An area designated where spectators view a high power rocket launch.

Tripoli (TRA). Tripoli Rocketry Association, Inc.

Requirements for High Power Rocket Operation

- 1 **Operating Clearances.** A person shall fly a high power rocket only in compliance with:
 - a. This code;
 - b. *Federal Aviation Administration Regulations*, Part 101 (Section 307.72 Statute 749, Title 49 United States Code, Section 1348, "Airspace Control and Facilities," Federal Aviation Act of 1958); and
 - c. Other applicable federal, state, and local laws, rules, regulations, statutes, and ordinances.
 - d. Landowner permission.

7/31/2012

2 Participation, Participation and Access at Tripoli Launches shall be limited to the following:

- 2-1** HPR Fliers may access and conduct flights from the High Power Launch Area and/or Model Rocket Launch Area.
- 2-2** Non-Tripoli Members age 18 and over that are students of an accredited educational institution may participate in joint projects with Tripoli members. These individuals are allowed in the High Power Launch Area and/or Model Rocket Launch Area if escorted by a Tripoli member. The maximum number of non member participants shall not exceed five (5) per Tripoli Member.
- 2-3** Non-Tripoli Members that are members of a Named Insured Group may participate in joint projects with Tripoli members. These individuals are allowed in the High Power Launch Area and/or Model Rocket Launch Area if escorted by a Tripoli member. The maximum number of non member participants shall not exceed five (5) per Tripoli Member.
- 2-4** Tripoli Junior Members that have successfully completed the Tripoli Mentoring Program Training may access and conduct flights from the High Power Launch Area while under the direct supervision of a Tripoli Senior member in accordance with the rules of the Tripoli Mentored Flying program. The Tripoli Senior member may provide supervision for up to five(5) individuals that have successfully completed the Tripoli Mentoring Program Training at a time in the High Power Launch Area.
- 2-5** Children younger than 18 years of age may conduct flights from the Model Rocket Launch Area under the direction of a HPR Flier.
- 2-6 Attendance by Invited Guests and Spectators**
 - 2-6.1** An invited guest may be permitted in the Model Rocket Launch Area and preparation areas upon approval of the RSO.
 - 2-6.2** An Invited Guest may be allowed in the High Power Launch Area if escorted by a HPR Flier. A HPR Flier may escort and be accompanied by not more than five (5) non-HPR fliers in the High Power Launch Area. The HPR flier escort is required to monitor the actions of the escorted non-HPR fliers, and the escort is fully responsible for those actions and for the safety of those escorted.
 - 2-6.3** Spectators, who are not invited guests, shall confine themselves to the spectator areas as designated by the RSO and shall not be present in the High Power Launch Area or Model Rocket Launch Area.

Referenced Publications

The following documents or portions thereof are referenced within this code. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

3-1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101

NFPA 1122, *Code for Model Rocketry*.

NFPA 1125, *Code for the Manufacture of Model Rocket Motors*.

NFPA 1127, *Code for High Power Rocketry*

3-2 Government Publications. Superintendent of Documents, U.S. Government Printing Office, Washington DC 20402.

Federal Aviation Administration Regulations, from the Code of Federal Regulations. Federal

7/31/2012

Hazardous Substances Act, from the United States Code (re. Airspace Control)

3-3 TRA Publications. Tripoli Rocketry Association, Inc., P. O. Box 87, Bellevue NE 68005.

Articles of Incorporation and Bylaws

High Power Rocketry Safety Code

Tripoli Motor Testing Committee (TMT), Testing Policies

Appendix A - Additional Tripoli Rulings

A-1 NFPA 1127 was adopted by the Tripoli Board of Directors as the Tripoli Safety Code. (*Tripoli Report*, April 1994, Tripoli Board Minutes, New Orleans, 21 January 1994, Motion 13.) Since this adoption, the code has gone through some revisions. Such is the way with codes – they are constantly undergoing change to improve and update them when safety prompts, or when the federal regulations change or are reinterpreted

A-2 All Tripoli members who participate in Association activities shall follow the Tripoli Certification Standards.

A-3 Any Board action(s), with regard to safety, made previous to or after publication of this document shall be a part of the Tripoli Safety Code.

A-4 Increased descent rates for rocket activities conducted at the Black Rock Desert venue are acceptable if needed to insure a controlled descent to remain inside the FAA approved Dispersion Area.

A-5 A rocket motor shall not be ignited by using:

- a. A switch that uses mercury.
- b. “Pressure roller” switches

This edition, and all other editions, of the High Power Rocketry Safety Code is Copyright ©2012 by the Tripoli Rocketry Association, Inc. All rights reserved. Reproduction in whole or in part without written permission is prohibited.

7/31/2012

E.3— Amateur Rockets Laws

101.21 Applicability.

- (a) This subpart applies to operating unmanned rockets. However, a person operating an unmanned rocket within a restricted area must comply with §101.25(b) (7) (ii) and with any additional limitations imposed by the using or controlling agency.
- (b) A person operating an unmanned rocket other than an amateur rocket as defined in §1.1 of this chapter must comply with 14 CFR Chapter III.

101.22 Definitions.

The following definitions apply to this subpart:

(A) *Class 1—Model Rocket* means an amateur rocket that:

- (1) uses no more than 125 grams (4.4 ounces) of propellant;
- (2) Uses a slow-burning propellant;
- (3) Is made of paper, wood, or breakable plastic;
- (4) Contains no substantial metal parts; and
- (5) Weighs no more than 1,500 grams (53 ounces), including the propellant.

(b) *Class 2—High-Power Rocket* means an amateur rocket other than a model rocket that is propelled by a motor or motors having a combined total impulse of 40,960 Newton-seconds (9,208 pound-seconds) or less.

(c) *Class 3—Advanced High-Power Rocket* means an amateur rocket other than a model rocket or high-power rocket.

101.23 General operating limitations.

- (a) You must operate an amateur rocket in such a manner that it:
 - (1) Is launched on a suborbital trajectory;
 - (2) When launched, must not cross into the territory of a foreign country unless an agreement is in place between the United States and the country of concern;
 - (3) Is unmanned; and
 - (4) Does not create a hazard to persons, property, or other aircraft.
- (b) The FAA may specify additional operating limitations necessary to ensure that air traffic is not adversely affected, and public safety is not jeopardized.

101.25 Operating limitations for Class 2-High Power Rockets and Class 3-Advanced High Power Rockets.

When operating *Class 2-High Power Rockets* or *Class 3-Advanced High Power Rockets*, you must comply with the General Operating Limitations of §101.23. In addition, you must not operate *Class 2-High Power Rockets* or *Class 3-Advanced High Power Rockets*—

- (a) At any altitude where clouds or obscuring phenomena of more than five-tenths coverage prevails;
- (b) At any altitude where the horizontal visibility is less than five miles;

- (c) Into any cloud;
- (d) Between sunset and sunrise without prior authorization from the FAA;
- (e) Within 9.26 kilometers (5 nautical miles) of any airport boundary without prior authorization from the FAA;
- (f) In controlled airspace without prior authorization from the FAA;
- (g) Unless you observe the greater of the following separation distances from any person or property that is not associated with the operations:
 - (1) Not less than one-quarter the maximum expected altitude;
 - (2) 457 meters (1,500 ft.);
- (h) Unless a person at least eighteen years old is present, is charged with ensuring the safety of the operation, and has final approval authority for initiating high-power rocket flight; and
- (i) Unless reasonable precautions are provided to report and control a fire caused by rocket activities.

101.27 ATC notification for all launches.

No person may operate an unmanned rocket other than a Class 1—Model Rocket unless that person gives the following information to the FAA ATC facility nearest to the place of intended operation no less than 24 hours before and no more than three days before beginning the operation:

- (a) The name and address of the operator; except when there are multiple participants at a single event, the name and address of the person so designated as the event launch coordinator, whose duties include coordination of the required launch data estimates and coordinating the launch event;
- (b) Date and time the activity will begin;
- (c) Radius of the affected area on the ground in nautical miles;
- (d) Location of the center of the affected area in latitude and longitude coordinates;
- (e) Highest affected altitude;
- (f) Duration of the activity;
- (g) Any other pertinent information requested by the ATC facility.

101.29 Information requirements.

(a) *Class 2—High-Power Rockets.* When a Class 2—High-Power Rocket requires a certificate of waiver or authorization, the person planning the operation must provide the information below on each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 2 rocket expected to be flown:

- (1) Estimated number of rockets,
- (2) Type of propulsion (liquid or solid), fuel(s) and oxidizer(s),
- (3) Description of the launcher(s) planned to be used, including any airborne platform(s),
- (4) Description of recovery system,
- (5) Highest altitude, above ground level, expected to be reached,
- (6) Launch site latitude, longitude, and elevation, and
- (7) Any additional safety procedures that will be followed.

(b) *Class 3—Advanced High-Power Rockets*. When a Class 3—Advanced High-Power Rocket requires a certificate of waiver or authorization the person planning the operation must provide the information below for each type of rocket to the FAA at least 45 days before the proposed operation. The FAA may request additional information if necessary to ensure the proposed operations can be safely conducted. The information shall include for each type of Class 3 rocket expected to be flown:

- (1) The information requirements of paragraph (a) of this section,
- (2) Maximum possible range,
- (3) The dynamic stability characteristics for the entire flight profile,
- (4) A description of all major rocket systems, including structural, pneumatic, propellant, propulsion, ignition, electrical, avionics, recovery, wind-weighting, flight control, and tracking,
- (5) A description of other support equipment necessary for a safe operation,
- (6) The planned flight profile and sequence of events,
- (7) All nominal impact areas, including those for any spent motors and other discarded hardware, within three standard deviations of the mean impact point,
- (8) Launch commits criteria,
- (9) Countdown procedures, and
- (10) Mishap procedures.

E.4 Law & Regulations: NAR

User Certification

NFPA Code 1127—and the safety codes of both the NAR and TRA—require that “high power motors” be sold to or possessed by only a certified user. This certification may be granted by a “nationally recognized organization” to people who demonstrate competence and knowledge in handling, storing, and using such motors. Currently only the NAR and TRA offer this certification service. Each organization has slightly different standards and procedures for granting this certification, but each recognizes certifications granted by the other. Certified users must be age 18 or older.

Explosives Permits

Hobby rocket motors (including high power) no longer require a Federal explosives permit to sell, purchase, store, or fly. Certain types of igniters, and cans or other bulk amounts of black powder do require such permits. Under the Organized Crime Control Act of 1970 (Public Law 91- 452). A Federal Low Explosives User Permit (LEUP) from the Bureau of Alcohol, Tobacco, and Firearms (BATF) is required to purchase these items outside one’s home state, or to transport them across state lines. These items, once bought under an LEUP, must thereafter be stored in a magazine that is under the control of an LEUP holder. A “Type 3” portable magazine or “Type 4” indoor magazine (described under NFPA Code 495) is required, and it can be located in an attached garage. BATF must inspect such magazines.

Federal permits can be obtained from the BATF using their Form 5400.13/5400.16, available from the ATF Distribution Center, 7943 Angus CT., Springfield, VA 22153. These are issued only to U.S. citizens, age 18 and older, who have no record of conviction of felonies and who pass a background check conducted by the BATF. This check includes a personal interview by a BATF agent.

Launch Site Requirements

The first requirement for any launch site is permission of the owner to use it for flying rockets! Use of land—even public property—without permission is usually illegal and always a bad way for a NAR member to demonstrate responsible citizenship. The NAR will issue “site owner” insurance to chartered sections to cover landowners against liability for rocket-flying accidents on their property—such insurance is normally required.

The NAR safety codes and NFPA Codes establish some minimum requirements for the size and surroundings of launch sites. Model rocket launch sites must have minimum dimensions which depend on the rocket’s motor power as specified in Rule 7 of the model rocket safety code and its accompanying table. The site within these dimensions must be “free of tall trees, power lines, buildings, and dry brush and grass”. The launcher can be anywhere on this site, and the site can include roads. Site dimensions are not tied to the expected altitude of the rockets’ flights.

According to the high-power safety code, high-power rocket launch sites must be free of these same obstructions, and within them the launcher must be located “at least 1500 feet from any occupied building” and at least “one quarter of the expected altitude” from any boundary of the site. NFPA Code 1127 establishes further requirements for the high-power site: it must contain no occupied buildings, or highways on which traffic exceeds 10 vehicles per hour; and the site must have a minimum dimension no less than either half the maximum expected rocket altitude or 1500 feet, whichever is greater—or it must comply with a table of minimum site dimensions from NFPA 1127 and the high power safety code.

While model rocketry and high power rocketry, when conducted in accordance with the NAR Safety Codes, are legal activities in all 50 states, some states impose specific restrictions on the activity (California being the worst example of this) and many local jurisdictions require some form of either notification or prior approval of the fire marshal. It is prudent and highly recommended that before you commit to a launch site you meet with the fire marshal having jurisdiction over the site to make him aware of what you plan to do there and build a relationship with him just as you did with the land owner. The fact that NAR rocketry is recognized and its safety and launch site requirements are codified in Codes 1122 (Model Rockets) and 1127 (High Power Rockets) by the National Fire Protection Association will be a very powerful part of your discussion with any fire marshal.

Airspace Clearance

The Federal Aviation Administration (FAA) has jurisdiction over the airspace of the U.S. and whatever flies in it. Their regulations concerning who may use it and under what conditions are known as the Federal Aviation Regulations (FAR)—which are also called Title 14 of the Code of

Federal Regulations (14 CFR). Chapter 1, Subchapter F, Part 101 of these regulations (14 CFR 101.1) specifically exempts model rockets that weigh 16 ounces or less and have 4 ounces or less of propellant from FAA regulation as long as they are “operated in a manner that does not create a hazard to persons, property, or other aircraft.” When operated in this safe manner, model rockets may be flown in any airspace, at any time, and at any distance from an airport—without prior FAA approval.

Rockets larger than these specific limits—i.e. all high-power rockets—are referred to as “unmanned rockets” by the FARs and are subject to very specific regulations. Such rockets may not be flown in controlled airspace (which is extensive in the U.S. even at low altitudes and includes all airspace above 14,500 feet), within 5 miles of the boundary of any airport, into cloud cover greater than 50% or visibility less than 5 miles, within 1500 feet of any person or property not associated with the operation, or between sunset and sunrise. Both NFPA Code 1127 and the NAR high-power safety code require compliance with all FAA regulations.

Deviation from these FAR limits for unmanned rockets requires either notification of or granting of a “waiver” by the FAA. Such a waiver grants permission to fly but does not guarantee exclusive use of the airspace. The information required from the flier by the FAA is detailed in section S 101.25 of the FAR (14 CFR 101.25). If the rockets are no more than 1500 grams with no more than 125 grams of propellant, no notification of or authorization by the FAA is required. Larger rockets require a specific positive response from the FAA Regional Office granting a waiver before flying may be conducted; and the waiver will require that you notify a specific FAA contact to activate a Notice to Airmen 24 hours prior to launch. The waiver is requested using FAA Form 7711-2, available from any FAA office or the FAA website. This form must be submitted in triplicate to the nearest FAA Regional Office 30 days or more in advance of the launch, and it is advisable to include supplemental information with it, including copies of the Sectional Aeronautical Chart with the launch site marked on it and copies of the high-power safety code. The FAA charges no fee.

Ignition Safety

The NAR safety codes and the NFPA Codes both require that rockets be launched from a distance by an electrical system that meets specific design requirements. Ignition of motors by a fuse lit by a hand-held flame is prohibited, and in fact both NFPA Codes prohibit the sale or use of such fuses. All persons in the launch area are required to be aware of each launch in advance (this means a PA system or other loud signal, especially for high-power ranges), and all (including photographers) must be a specified minimum distance from the pad prior to launch. This “safe distance” depends on the power of the motors in the rocket; the rules are different for model rockets and high-power rockets. Both the field size and the pad layout at a rocket range—particularly a high-power range—must take into account and support the size of the rockets that will be allowed to fly on the range.

For model rockets, the “safe distance” depends on the total power of all motors being ignited on the pad: 15 feet for 30 N-sec or less and 30 feet for more than 30 N-sec. For high-power rockets, the distance depends on the total power of all motors in the rocket, regardless of how many are

being ignited on the pad, and on whether the rocket is “complex”, i.e. multistage or propelled by a cluster of motors. The distance can range from 50 feet for a rocket with a single ‘H’ motor to 2000 feet for a complex rocket in the ‘O’ power class. These distances are specified in a table in NFPA Code 1127 and the NAR high-power safety code.

Motor Certification

Both NAR safety codes and both NFPA Codes require that fliers use only “certified” motors. This certification requires passing a rigorous static testing program specified in the NFPA Codes. The NAR safety codes and insurance require that NAR members use only NAR certified motors; and since the NAR currently has a reciprocity agreement with TRA on motor certification, this means that TRA- certified motors also have NAR certification. The NFPA Codes recognize certifications granted by any “approved testing laboratory or national user organization”, but only the NAR and TRA can provide this service in most parts of the country. The California Fire Marshal has his own testing program for motors in that state. Motors made by private individuals or by companies without proper explosives licenses, and motors not formally classified for shipment by the U.S. Department of Transportation, are not eligible for NAR certification and may not be used on an NAR range.

Shipping of Motors

Sport rocket motors generally contain highly flammable substances such as black powder or ammonium perchlorate, and are therefore considered to be hazardous materials or explosives for shipment purposes by the U.S. Department of Transportation (DOT). There are extensive regulations concerning shipment in the DOT’s section of the CFR—Title 49, Parts 170-179. These regulations cover packaging, labeling, and the safety testing and classification that is required prior to shipment. These regulations are of great concern to manufacturers and dealers, and there are severe penalties for non-compliance. Basically, it is illegal to send rocket motors by UPS, mail, Federal Express, or any other common carrier—or to carry them onto an airliner—except under exact compliance with these regulations. The reality of these regulations, and the shippers’ company regulations, is that it is virtually impossible for a private individual to legally ship a rocket motor of any size. Transportation of motors on airlines is very difficult to do legally and should be avoided if at all possible. It takes weeks of advance effort with the airline, and in the post-September 11 world is probably not even worth attempting.

Insurance

Most property owners, whether government bodies or private owners, will demand the protection of liability insurance as a precondition to granting permission to fly sport rockets on their property. The NAR offers such insurance to individual fliers, to chartered NAR sections, and to flying site owners. Individual insurance is automatic for all NAR members. It covers only the insured individual, not the section or the site owner. Under the current underwriter this insurance runs for a 12 month period, coincident with NAR membership.

Sections are insured as a group for a year; remember that section insurance is coincident with the section charter and expires on April 4 each year. Site owner insurance is available to all active sections for free. Each site owner insurance certificate covers only a single site (launch

field or meeting room). NAR insurance covers only activities that are conducted in accordance with the NAR safety code using NAR-certified motors. It provides \$2 -million aggregate liability coverage for damages from bodily injury or property damage claims resulting from sport rocket activities such as launches, meetings, or classes and \$1 million coverage for fire damage to the launch site. It is “primary” above any other insurance you may have.

References

NFPA Code 495, Explosives Materials Code, National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

NFPA Code 1122, Code for Model Rocketry. NFPA Code 1127, Code for High Power Rocketry. Code of Federal Regulations, Title 14, Part 101, Federal Aviation Regulations by the FAA for unmanned rockets.

Code of Federal Regulation, Title 16, Part 1500.85(a)(8), Consumer Product Safety Commission exemption for model rockets.

Code of Federal Regulations, Title 27, Part 55, Bureau of Alcohol, Tobacco, and Firearms regulations.

Code of Federal Regulations, Title 49, Parts 170-177, Department of Transportation hazardous material shipping regulations.

Model Rocket Safety Code, National Association of Rocketry.

High Power Rocketry Safety Code, National Association of Rocketry.

APPENDIX F: MSDS

MATERIAL SAFETY DATA SHEET

West System Inc.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: WEST SYSTEM® 105 Epoxy Resin
 PRODUCT CODE: 105
 CHEMICAL FAMILY: Epoxy Resin
 CHEMICAL NAME: Bisphenol A based epoxy resin.
 FORMULA: Not applicable.

MANUFACTURER:
 West System Inc.
 102 Patterson Ave.
 Bay City, MI 48706, U.S.A.
 Phone: 866-937-8797 or 989-684-7286
 www.westsystem.com

EMERGENCY TELEPHONE NUMBERS:
 Transportation
 CHEMTREC: 800-424-9300 (U.S.)
 703-527-3887 (International)
 Non-transportation
 Poison Hotline: 800-222-1222

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

WARNING May cause skin irritation. May cause eye irritation. May cause allergic reaction. Clear, viscous liquid with mild odor.

PRIMARY ROUTE(S) OF ENTRY: Skin contact.

POTENTIAL HEALTH EFFECTS:

ACUTE INHALATION: If product is heated, vapors generated can cause headache, nausea, dizziness and possible respiratory irritation if inhaled in high concentrations.

CHRONIC INHALATION: Repeated exposure to high vapor concentrations may cause irritation of pre-existing lung allergies and increase the chance of developing allergy symptoms to this product.

ACUTE SKIN CONTACT: May cause allergic skin response in certain individuals. May cause moderate irritation to the skin such as redness and itching.

CHRONIC SKIN CONTACT: May cause sensitization in susceptible individuals. May cause moderate irritation to the skin.

EYE CONTACT: May cause irritation.

INGESTION: Low acute oral toxicity.

SYMPTOMS OF OVEREXPOSURE: Possible sensitization and subsequent allergic reactions usually seen as redness and rashes.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Pre-existing skin and respiratory disorders may be aggravated by exposure to this product. Pre-existing lung and skin allergies may increase the chance of developing allergic symptoms to this product.

3. COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS

INGREDIENT NAME	CAS #	CONCENTRATION (%)
Propane, 2,2-bis[p-(2,3-epoxypropoxy)phenyl]-, polymers	25085-99-8	60-100
Benzyl alcohol	100-51-6	10-30
Phenol-formaldehyde polymer glycidyl ether	28064-14-4	1-10

4. FIRST AID MEASURES

FIRST AID FOR EYES: Flush immediately with water for at least 15 minutes. Consult a physician.

FIRST AID FOR SKIN: Remove contaminated clothing. Wipe excess from skin. Apply waterless skin cleaner and then wash with soap and water. Consult a physician if effects occur.

FIRST AID FOR INHALATION: Remove to fresh air if effects occur.

FIRST AID FOR INGESTION: No acute adverse health effects expected from amounts ingested under normal conditions of use. Seek medical attention if a significant amount is ingested.

5. FIRE FIGHTING MEASURES

FLASH POINT: >200°F (Tag Closed Cup)

EXTINGUISHING MEDIA: Foam, carbon dioxide (CO₂), dry chemical.

SPECIAL FIRE FIGHTING PROCEDURES: Wear a self-contained breathing apparatus and complete full-body personal protective equipment. Closed containers may rupture (due to buildup of pressure) when exposed to extreme heat.

FIRE AND EXPLOSION HAZARDS: During a fire, smoke may contain the original materials in addition to combustion products of varying composition which may be toxic and/or irritating. Combustion products may include, but are not limited to: phenolics, carbon monoxide, carbon dioxide.

6. ACCIDENTAL RELEASE MEASURES

SPILL OR LEAK PROCEDURES: Stop leak without additional risk. Dike and absorb with inert material (e.g., sand) and collect in a suitable, closed container. Warm, soapy water or non-flammable, safe solvent may be used to clean residual.

7. HANDLING AND STORAGE

STORAGE TEMPERATURE (min./max.): 40°F (4°C) / 120°F (49°C)

STORAGE: Store in cool, dry place. Store in tightly sealed containers to prevent moisture absorption and loss of volatiles. Excessive heat over long periods of time will degrade the resin.

HANDLING PRECAUTIONS: Avoid prolonged or repeated skin contact. Wash thoroughly after handling. Launder contaminated clothing before reuse. Avoid inhalation of vapors from heated product. Precautionary steps should be taken when curing product in large quantities. When mixed with epoxy curing agents this product causes an exothermic, which in large masses, can produce enough heat to damage or ignite surrounding materials and emit fumes and vapors that vary widely in composition and toxicity.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

EYE PROTECTION GUIDELINES: Safety glasses with side shields or chemical splash goggles.

SKIN PROTECTION GUIDELINES: Wear liquid-proof, chemical resistant gloves (nitrile-butyl rubber, neoprene, butyl rubber or natural rubber) and full body-covering clothing.

RESPIRATORY/VENTILATION GUIDELINES: Good room ventilation is usually adequate for most operations. Wear a NIOSH/MSHA approved respirator with an organic vapor cartridge whenever exposure to vapor in concentrations above applicable limits is likely.

Note: West System, Inc. has conducted an air sampling study using this product or similarly formulated products. The results indicate that the components sampled for (epichlorohydrin, benzyl alcohol) were either so low that they were not detected at all or they were significantly below OSHA's permissible exposure levels.

ADDITIONAL PROTECTIVE MEASURES: Practice good caution and personal cleanliness to avoid skin and eye contact. Avoid skin contact when removing gloves and other protective equipment. Wash thoroughly after handling. Generally speaking, working cleanly and following basic precautionary measures will greatly minimize the potential for harmful exposure to this product under normal use conditions.

OCCUPATIONAL EXPOSURE LIMITS: Not established for product as whole. Refer to OSHA's Permissible Exposure Level (PEL) or the ACGIH Guidelines for information on specific ingredients.

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL FORM: Liquid.

COLOR: Clear.

ODOR: Mild.

BOILING POINT: > 400°F

MELTING POINT/FREEZE POINT: No data.

VISCOSITY: 1000 (cP)

pH: No data.

SOLUBILITY IN WATER: Slight.

SPECIFIC GRAVITY: 1.15

BULK DENSITY: 9.6 (pounds/gallon)

VAPOR PRESSURE: < 1 mmHg @ 20°C.

VAPOR DENSITY: Heavier than air.

% VOLATILE BY WEIGHT: ASTM D 2369-07 was used to determine the Volatile Content of mixed epoxy resin and hardener. Refer to the hardener's MSDS for information about the total volatile content of the resin/hardener system.

10. STABILITY AND REACTIVITY

STABILITY: Stable.

HAZARDOUS POLYMERIZATION:..... Will not occur by itself, but a mass of more than one pound of product plus an aliphatic amine will cause irreversible polymerization with significant heat buildup.

INCOMPATIBILITIES:..... Strong acids, bases, amines and mercaptans can cause polymerization.

DECOMPOSITION PRODUCTS:..... Carbon monoxide, carbon dioxide and phenolics may be produced during uncontrolled exothermic reactions or when otherwise heated to decomposition.

11. TOXICOLOGICAL INFORMATION

No specific oral, inhalation or dermal toxicology data is known for this product. Specific toxicology information for a bisphenol-A based epoxy resin present in this product is indicated below:

Oral:..... LD₅₀ >5000 mg/kg (rats)
Inhalation:..... No Data.
Dermal:..... LD₅₀ = 20,000 mg/kg (skin absorption in rabbits)

TERATOLOGY:..... Diglycidyl ether bisphenol-A (DGEBA) did not cause birth defects or other adverse effects on the fetus when pregnant rabbits were exposed by skin contact, the most likely route of exposure, or when pregnant rats or rabbits were exposed orally.

REPRODUCTIVE EFFECTS:..... DGEBA, in animal studies, has been shown not to interfere with reproduction.

MUTAGENICITY:..... DGEBA. In animal mutagenicity studies were negative. In vitro mutagenicity tests were negative in some cases and positive in others.

CARCINOGENICITY:

NTP..... Product not listed.
IARC..... Product not listed.
OSHA..... Product not listed.

No ingredient of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA, NTP or IARC.

Many studies have been conducted to assess the potential carcinogenicity of diglycidyl ether of bisphenol-A. Although some weak evidence of carcinogenicity has been reported in animals, when all of the data are considered, the weight of evidence does not show that DGEBA is carcinogenic. Indeed, the most recent review of the available data by the International Agency for Research on Cancer (IARC) has concluded that DGEBA is not classified as a carcinogen.

Epichlorohydrin, an impurity in this product (~5 ppm) has been reported to produce cancer in laboratory animals and to produce mutagenic changes in bacteria and cultured human cells. It has been established by the International Agency for Research on Cancer (IARC) as a probable human carcinogen (Group 2A) based on the following conclusions: human evidence – inadequate; animal evidence – sufficient. It has been classified as an anticipated human carcinogen by the National Toxicology Program (NTP). Note: It is unlikely that normal use of this product would result in measurable exposure concentrations to this substance.

12. ECOLOGICAL INFORMATION

In the non-cured liquid form this product may cause long-term harm if released to the environment. Prevent entry into sewers and natural waters.

Movement and Partitioning:
Bioconcentration potential is moderate (BCF between 100 and 3000 or Log K_{ow} between 3 and 5).

Degradation and Transformation:
Theoretical oxygen demand is calculated to be 2.35 p/p. 20-day biochemical oxygen demand is <2.5%.

Ecotoxicology:
Material is moderately toxic to aquatic organisms on an acute basis. LC50/EC50 between 1 and 10 mg/L in most sensitive species.

13. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD:..... Evaluation of this product using RCRA criteria shows that it is not a hazardous waste, either by listing or characteristics, in its purchased form. It is the responsibility of the user to determine proper disposal methods.

Incinerate, recycle (fuel blending) or reclaim may be preferred methods when conducted in accordance with federal, state and local regulations.

14. TRANSPORTATION INFORMATION

DOT Non-Bulk
SHIPPING NAME:..... Not regulated.
TECHNICAL SHIPPING NAME:..... Not applicable.

HAZARD CLASS: Not applicable.
 U.N./N.A. NUMBER: Not applicable.
 PACKING GROUP: Not applicable.

IMDG
 SHIPPING NAME: Environmentally hazardous substance, liquid, n.o.s.
 TECHNICAL SHIPPING NAME: Epoxy Resin.
 HAZARD CLASS: Class 9.
 U.N. NUMBER: UN3082.
 PACKING GROUP: PG III.
 Ems Number: F-A, S-F
 MARINE POLLUTANT: Yes

ICAO/IATA
 SHIPPING NAME: Environmentally hazardous substance, liquid, n.o.s.
 TECHNICAL SHIPPING NAME: Epoxy Resin.
 HAZARD CLASS: Class 9.
 U.N. NUMBER: UN3082.
 PACKING GROUP: PG III.
 MARINE POLLUTANT: Yes

15. REGULATORY INFORMATION

OSHA STATUS: Irritant.
 TSCA STATUS: All components are listed on TSCA inventory or otherwise comply with TSCA requirements.
 Canada WHMIS Classification: D2B - Toxic material causing other toxic effects.
 CEPA Chemical Inventory Status: All components are listed or are otherwise compliant with CEPA requirements.

SARA TITLE III:
 SECTION 313 TOXIC CHEMICALS None (de minimus).

STATE REGULATORY INFORMATION:
 The following chemicals are specifically listed or otherwise regulated by individual states. For details on your regulatory requirements you should contact the appropriate agency in your state.

COMPONENT NAME CAS NUMBER	CONCENTRATION	STATE CODE
Epichlorohydrin 106-89-8	< 5ppm	¹ CA
Benzyl alcohol 100-51-6		MA, PA, NJ

¹ These substances are known to the state of California to cause cancer or reproductive harm, or both.

16. OTHER INFORMATION

REASON FOR ISSUE: Changes made in Section 14 and 15.
 PREPARED BY: G. M. House
 APPROVED BY: G. M. House
 TITLE: Health, Safety & Environmental Manager
 APPROVAL DATE: April 26, 2013
 SUPERSEDES DATE: March 9, 2012
 MSDS NUMBER: 105-13a

This information is furnished without warranty, expressed or implied, except that it is accurate to the best knowledge of West System Inc. The data on this sheet is related only to the specific material designated herein. West System Inc. assumes no legal responsibility for use or reliance upon these data.

MATERIAL SAFETY DATA SHEET

West System Inc.

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME: WEST SYSTEM® 205 Fast Hardener
 PRODUCT CODE: 205
 CHEMICAL FAMILY: Amine
 CHEMICAL NAME: Modified aliphatic polyamine
 FORMULA: Not applicable

MANUFACTURER:
 West System Inc.
 102 Patterson Ave.
 Bay City, MI 48706, U.S.A.
 Phone: 866-937-8797 or 989-684-7286
 www.westsystem.com

EMERGENCY TELEPHONE NUMBERS:
 Transportation
 CHEMTREC: 800-424-9300 (U.S.)
 703-527-3887 (international)
 Non-transportation
 Poison Hotline: 800-222-1222

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

DANGER Causes burns to eyes and skin. Harmful if swallowed. Harmful if absorbed through the skin. May be harmful if inhaled. May cause allergic reaction. Amber colored liquid with ammonia odor.

PRIMARY ROUTE(S) OF ENTRY: Skin contact, eye contact, Inhalation.

POTENTIAL HEALTH EFFECTS:

ACUTE INHALATION: May cause respiratory tract irritation. Coughing and chest pain may result.

CHRONIC INHALATION: May cause respiratory tract irritation, coughing, sore throat, shortness of breath or chest pain.

ACUTE SKIN CONTACT: May cause strong irritation, redness. Possible mild corrosion.

CHRONIC SKIN CONTACT: Prolonged or repeated contact may cause an allergic reaction and possible sensitization in susceptible individuals. Large dose skin contact may result in material being absorbed in harmful amounts.

EYE CONTACT: Moderate to severe irritation with possible tissue damage. Concentrated vapors can be absorbed in eye tissue and cause eye injury. Contact causes discomfort and possible corneal injury or conjunctivitis.

INGESTION: Single dose oral toxicity is moderate. May cause gastrointestinal tract irritation and pain. Aspiration hazard.

SYMPTOMS OF OVEREXPOSURE: Respiratory tract irritation. Skin irritation and redness. Possible allergic reaction seen as hives and rash. Eye irritation. Possible liver and kidney disorders upon long term skin absorption overexposures.

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Chronic respiratory disease, asthma. Eye disease. Skin disorders and allergies.

3. COMPOSITION/INFORMATION ON HAZARDOUS INGREDIENTS

INGREDIENT NAME	CAS #	CONCENTRATION (%)
Reaction products of triethylenetetramine with phenol/formaldehyde	32610-77-8	40-70
Polyethylenepolyamines	68131-73-7	10-30
Triethylenetetramine	112-24-3	5-20
Hydroxybenzene	108-95-2	1-10
Reaction products of triethylenetetramine and propylene oxide	26950-63-0	1-10
Tetraethylenepentamine	112-57-2	1-10

4. FIRST AID MEASURES

FIRST AID FOR EYES: Immediately flush with water for at least 15 minutes. Get prompt medical attention.

FIRST AID FOR SKIN: Remove contaminated clothing. Immediately wash skin with soap and water. Do not apply greases or ointments. Get medical attention if severe exposure.

FIRST AID FOR INHALATION: Move to fresh air and consult physician if effects occur.

FIRST AID FOR INGESTION: Give conscious person at least 2 glasses of water. Do not induce vomiting. If vomiting should occur spontaneously, keep airway clear. Get medical attention.

5. FIRE FIGHTING MEASURES

FLASH POINT: >270°F (PMCC)

EXTINGUISHING MEDIA: Dry chemical, alcohol foam, carbon dioxide (CO₂), dry sand, limestone powder.

FIRE AND EXPLOSION HAZARDS: During a fire, smoke may contain the original materials in addition to combustion products of varying composition which may be toxic and/or irritating. Combustion products may include, but are not limited to: oxides of nitrogen, carbon monoxide, carbon dioxide, volatile amines, ammonia, nitric acid, nitrosamines. When mixed with sawdust, wood chips, or other cellulosic material, spontaneous combustion can occur under certain conditions. Heat is generated as the air oxidizes the amine. If the heat is not dissipated quickly enough, it can ignite the sawdust.

SPECIAL FIRE FIGHTING PROCEDURES: Use full-body protective gear and a self-contained breathing apparatus. Use of water may generate toxic aqueous solutions. Do not allow water run-off from fighting fire to enter drains or other water courses.

6. ACCIDENTAL RELEASE MEASURES

SPILL OR LEAK PROCEDURES: Stop leak without additional risk. Wear proper personal protective equipment. Dike and contain spill. Ventilate area. Large spill - dike and pump into appropriate container for recovery. Small spill - recover or use inert, non-combustible absorbent material (e.g., sand, clay) and shovel into suitable container. Do not use sawdust, wood chips or other cellulosic materials to absorb the spill, as the possibility for spontaneous combustion exists. Wash spill residue with warm, soapy water if necessary.

7. HANDLING AND STORAGE

STORAGE TEMPERATURE (min./max.): 40°F (4°C) / 90°F (32°C).

STORAGE: Store in cool, dry place away from high temperatures and moisture. Keep container tightly closed.

HANDLING PRECAUTIONS: Use with adequate ventilation. Do not breathe vapors or mists from heated material. Avoid exposure to concentrated vapors. Avoid skin contact. Wash thoroughly after handling. When mixed with epoxy resin this product causes an exothermic reaction, which in large masses, can produce enough heat to damage or ignite surrounding materials and emit fumes and vapors that vary widely in composition and toxicity.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

EYE PROTECTION GUIDELINES: Chemical splash-proof goggles or face shield.

SKIN PROTECTION GUIDELINES: Wear liquid-proof, chemical resistant gloves (nitrile-butyl rubber, neoprene, butyl rubber or natural rubber) and full body-covering clothing.

RESPIRATORY/VENTILATION GUIDELINES: Use with adequate general and local exhaust ventilation to meet exposure limits. In poorly ventilated areas, use a NIOSH/MSHA approved respirator with an organic vapor cartridge.

Note: West System, Inc. has conducted an air sampling study using this product or similarly formulated products. The results indicate that the components sampled for (phenol, formaldehyde and amines) were either so low that they were not detected at all or they were well below OSHA's permissible exposure levels.

ADDITIONAL PROTECTIVE MEASURES: Use where there is immediate access to safety shower and emergency eye wash. Wash thoroughly after use. Contact lens should not be worn when working with this material. Generally speaking, working cleanly and following basic precautionary measures will greatly minimize the potential for harmful exposure to this product under normal use conditions.

OCCUPATIONAL EXPOSURE LIMITS: Not established for product as whole. Refer to OSHA's Permissible Exposure Level (PEL) or the ACGIH Guidelines for information on specific ingredients.

9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL FORM Liquid.
COLOR Amber.
ODOR Ammonia-like.
BOILING POINT > 440°F.
MELTING POINT/FREEZE POINT Approximately 23°F.
pH Alkaline.

SOLUBILITY IN WATER.....Appreciable.
 SPECIFIC GRAVITY.....1.05
 BULK DENSITY.....8.85 pounds/gallon.
 VAPOR PRESSURE.....< 1 mmHg @ 20°C.
 VAPOR DENSITY.....Heavier than air.
 VISCOSITY.....1,000 cPs
 % VOLATILE BY WEIGHT.....ASTM 2369-07 was used to determine the Volatile Matter Content of mixed epoxy resin and hardener. 105 Resin and 205 Hardener, mixed together at 5:1 by weight, has a density of 1137 g/L (9.49 lbs/gal). The combined VOC content for 105/205 is 7.91 g/L (0.07 lbs/gal).

10. STABILITY AND REACTIVITY

STABILITY:.....Stable.
 HAZARDOUS POLYMERIZATION:.....Will not occur.
 INCOMPATIBILITIES:.....Avoid excessive heat. Avoid acids, oxidizing materials, halogenated organic compounds (e.g., methylene chloride). External heating or self-heating could result in rapid temperature increase and serious hazard. If such a reaction were to take place in a waste drum, the drum could expand and rupture violently.
 DECOMPOSITION PRODUCTS:.....Very toxic fumes and gases when burned or otherwise heated to decomposition. Decomposition products may include, but not limited to: oxides of nitrogen, volatile amines, ammonia, nitric acid, aldehydes, nitrosamines.

11. TOXICOLOGICAL INFORMATION

No specific oral, inhalation or dermal toxicology data is known for this product.
 Oral:.....Expected to be moderately toxic.
 Inhalation:.....Expected to be moderately toxic.
 Dermal:.....Expected to be moderately toxic.
 Adsorption of phenolic solutions through the skin may be very rapid and can cause death. Lesser exposures can cause damage to the kidney, liver, pancreas and spleen; and cause edema of the lungs. Chronic exposures can cause death from liver and kidney damage.
 CARCINOGENICITY:
 NTP.....No.
 IARC.....No.
 OSHA.....No.
 No ingredient of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA, NTP or IARC.

12. ECOLOGICAL INFORMATION

In the non-cured, liquid form, this product may be harmful if released to the environment. Do not allow into sewers, on the ground or in any body of water.

13. DISPOSAL CONSIDERATIONS

WASTE DISPOSAL METHOD:.....Evaluation of this product using RCRA criteria shows that it is not a hazardous waste, either by listing or characteristics, in its purchased form. It is the responsibility of the user to determine proper disposal methods.
 Incinerate, recycle (fuel blending) or reclaim may be preferred methods when conducted in accordance with federal, state and local regulations.

14. TRANSPORTATION INFORMATION

DOT Non-Bulk
 SHIPPING NAME:.....Polyamines, liquid, corrosive, n.o.s.
 TECHNICAL SHIPPING NAME:.....Triethylenetetramine
 HAZARD CLASS:.....Class 8
 U.N./N.A. NUMBER:.....UN 2735
 PACKING GROUP:.....PG III
 MARINE POLLUTANT:.....No
 ICAO/IATA
 SHIPPING NAME:.....Polyamines, liquid, corrosive, n.o.s.
 TECHNICAL SHIPPING NAME:.....Triethylenetetramine
 HAZARD CLASS:.....Class 8
 U.N. NUMBER:.....UN 2735
 PACKING GROUP:.....PG III

MARINE POLLUTANT: No

IMDG

SHIPPING NAME: Polyamines, liquid, corrosive, n.o.s.
 TECHNICAL SHIPPING NAME: Triethylenetetramine
 HAZARD CLASS: Class 8
 U.N. NUMBER: UN 2735
 PACKING GROUP: PG III
 EmS Number: F-A, S-B
 MARINE POLLUTANT: No

15. REGULATORY INFORMATION

OSHA STATUS: Corrosive; possible sensitizer.

TSCA STATUS: All components listed on TSCA inventory or otherwise comply with TSCA requirements.

Canada WHMIS Classification: D2A – Very toxic material causing other toxic effects; E – Corrosive

CEPA Chemical Inventory Status: All components are listed or are otherwise compliant with CEPA requirements.

SARA TITLE III:

SECTION 313 TOXIC CHEMICALS: This product contains hydroxybenzene (phenol) and is subject to the reporting requirements of Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 and 40 CFR Part 372.

STATE REGULATORY INFORMATION:

The following chemicals are specifically listed or otherwise regulated by individual states. For details on your regulatory requirements you should contact the appropriate agency in your state.

COMPONENT NAME /CAS NUMBER	CONCENTRATION	STATE CODE
Tetraethylenepentamine 112-57-2		MA, NJ, PA
Tetraethylenetriamine 112-24-3		MA, NJ, PA
Phenol 108-95-2		NJ, RI, PA, MA, IL

16. OTHER INFORMATION

REASON FOR ISSUE: Changes made in Sections 5, 10, 14 & 15.

PREPARED BY: G. M. House

APPROVED BY: G. M. House

TITLE: Health, Safety & Environmental Manager

APPROVAL DATE: April 26, 2013

SUPERSEDES DATE: February 10, 2011

MSDS NUMBER: 205-13a

This information is furnished without warranty, expressed or implied, except that it is accurate to the best knowledge of West System Inc. The data on this sheet is related only to the specific material designated herein. West System Inc. assumes no legal responsibility for use or reliance upon these data.



Material Safety Data Sheet

Section 1: PRODUCT AND COMPANY IDENTIFICATION

MSDS Identification: Carbon Fabric, Sized or Unsized

MSDS Number: 439-3227-00SU-C000-12 **Date:** October 1, 2002 **Page:** 1 of 6

Supersedes MSDS: 439-3227-00SU-C000-11

Manufacturer:
Hexcel Schwebel
2200 South Murray Avenue
P.O. Box 2627
Anderson, SC 29621

Emergency Telephone Number:
800-433-5072 (24-Hour)

Information Telephone Number:
864-260-5799 (Normal Business Hours-ET)

Product Identification: Carbon Fabric: Sized or Unsized

Chemical Family: Woven Carbon Fabric with various types of Sized and Unsized Carbon Fibers.

Section 2: COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS® Number	% by Weight	OSHA(PEL)	ACGIH®(TLV®)
Carbon fiber, synthetic	7440-44-0	98.5-100	15 mg/m ³ (Total) 5 mg/m ³ (Respirable)	10 mg/m ³ (Total) 3 mg/m ³ (Respirable)

This product is not classified as a Hazardous Chemical as defined by the OSHA Hazard Communication Standard, 29 CFR 1910.1200.

Where specific exposure limits for component dusts are not established, the levels provided for (Total/Inhalable) dust and (Respirable) fraction reflect the classification of Particulates Not Otherwise Regulated (PNOR) by OSHA or Specified (PNOS) by ACGIH®.

Section 3: HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:

Appearance and Odor:

Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor.

Statement of Hazard:

Warning! May cause temporary mechanical irritation of the eyes, skin or upper respiratory tract.

If sized, vapor or fumes generated from heating or curing this product may cause eye and respiratory tract irritation.

Carbon fibers or dust are electrically conductive and may create electrical short-circuits which could result in damage to and malfunction of electrical equipment and/or personal injury.

Section 3: HAZARDS IDENTIFICATION (Continued)

EMERGENCY OVERVIEW (continued):**Primary Routes of Exposure:**

Eye--Yes	Skin--Yes	Inhalation--Yes	Ingestion--No
----------	-----------	-----------------	---------------

HMIS® Rating:

Health--1	Flammability--0	Reactivity--0	Special--None
-----------	-----------------	---------------	---------------

Potential Health Effects:

Eye: Contact may cause mechanical irritation to the eyes. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the eyes. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Skin: Contact may cause mechanical irritation to the skin and possible dermatitis. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Inhalation: May cause mechanical irritation to the upper respiratory tract. If sized, vapor or fumes from exposure of this product to elevated temperatures may cause irritation to the respiratory tract. Dust from machining, grinding or sawing the cured product may cause mechanical irritation.

Ingestion: Ingestion unlikely under normal conditions of use. If any of this product or the cured product dust is swallowed, seek medical attention immediately.

Medical Conditions Aggravated by Exposure: Preexisting eye, skin or respiratory disorders may be aggravated by exposure to this product or to the dust from machining, grinding or sawing the cured product.

Carcinogenic Information: None of the components present in this material at concentrations equal to or greater than 0.1 % are listed or regulated by IARC, NTP, OSHA or ACGIH® as a carcinogen.

Other:	OSHA(PEL)	ACGIH®(TLV®)
Exposure limits for cured product dust as [Particulates Not Otherwise Regulated (PNOR) by OSHA or Specified (PNOS) by ACGIH®]:	15 mg/m ³ (Total) 5 mg/m ³ (Respirable)	10 mg/m ³ (Inhalable) 3 mg/m ³ (Respirable)

Section 4: FIRST AID MEASURES

Eye: In case of eye contact, immediately flush eyes with large amounts of water for at least 15 minutes, keeping the eyelids open. Get medical attention immediately.

Skin: In case of contact that causes irritation, immediately wash skin with soap and room temperature to cool running water. Use a washcloth to help remove the fibers. To avoid further irritation, do not rub or scratch irritated areas. Rubbing or scratching may force fibers into the skin. Get medical attention immediately, if the irritation persists.

Inhalation: If large amounts of dust, fiber, fumes or vapor are inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, qualified personnel may administer oxygen. Get medical attention immediately.

Section 4: FIRST AID MEASURES (Continued)

Ingestion: Ingestion of this product or the dust from it is unlikely. If swallowed, get medical attention immediately.

Section 5: FIRE FIGHTING MEASURES

Flash Point/Method of Determination: Not determined

Means of Extinction: Use water spray, dry chemical or CO₂ to extinguish fires.

Special Fire Hazards: Avoid exposure through use of a self-contained, positive-pressure breathing apparatus.

Section 6: ACCIDENTAL RELEASE MEASURES

Procedures in case of Accidental Release or Leakage: Avoid contact with skin, eyes or clothing (See Section 8). Clean up material, put into a suitable container and dispose of properly (See Section 13).

Section 7: HANDLING AND STORAGE

Precautions to be taken in Handling and Storage: Store in a cool, dry place. Maintain sealed against contamination from dirt and moisture.

Section 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Eye/Face Protection: Avoid eye contact. Wear safety glasses with side shields, as necessary, when using this product or when machining, grinding or sawing the cured product.

Skin Protection: Protective clothing such as a loose fitting long sleeved shirt that covers to the base of the neck, long pants and gloves, as necessary to prevent irritation. Skin irritation is known to occur primarily at pressure points such as around the neck, wrist, waist and between the fingers.

Respiratory Protection: Not ordinarily required. If sized and sufficient vapor or fumes are being generated during heating or curing of this product, use a NIOSH approved organic vapor respirator. If sufficient dust or fibers are generated during use or when machining, grinding or sawing the cured product, use a NIOSH approved dust respirator.

Ventilation: Use local exhaust sufficient to control vapor, fumes, fibers or dust generated. If exhaust ventilation is not available or is inadequate, use a NIOSH approved respirator, as appropriate.

General Hygiene Recommendations: Before eating, drinking, smoking or using toilet facilities, wash face and hands thoroughly with soap and water. Remove any contaminated clothing and launder before reuse. Use vacuum equipment to remove fibers and dust from clothing and work areas. Compressed air is not recommended.

Section 9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Odor...Black fibers woven into fabrics of varying weight, width and thickness, depending on the style, with and without sizing, with no distinctive odor.

Melting Point (°F/°C)..... 6512°F/3600°C

Specific Gravity (Water=1)..... 1.5-1.9

pH of Undiluted Product..... Not determined

Volatile [Percent (%) by Weight]..... 0

Percent (%) VOC..... Not determined

Solubility in Water..... Negligible

Section 10: STABILITY AND REACTIVITY

Stability: Stable under proper handling and storage conditions

Incompatible Materials: None

Products evolved from Heat of Combustion or Decomposition: The products of combustion and decomposition depend on other materials present in the fire and the actual conditions of the fire. Burning will decompose the sizing system, if appropriate, and produce carbon and nitrogen oxides, phenols, aldehydes, acrolein, carboxylic acid, traces of incompletely burned carbon products and other unidentified gases and vapors that may be toxic. Avoid inhalation.

Hazardous Polymerization: Will not occur under proper conditions of use. Rapid heating of the product in bulk may produce an uncontrolled exothermic reaction that may char and decompose the sizing system, if appropriate, generating unidentified gases and vapors that may be toxic. Avoid inhalation.

Section 11: TOXICOLOGICAL INFORMATION

Component Toxicity Data:

Median Lethal Dose (Species):

Oral (LD₅₀)...Not determined

Inhalation (LC₅₀)...Not determined

Dermal (LD₅₀)...Not determined

Irritation Index, Estimation of Irritation (Species):

Skin...Not determined

Eyes...Not determined

Inhalation...Not determined

Section 12: ECOLOGICAL INFORMATION

No ecological data has been determined.

Section 13: DISPOSAL CONSIDERATIONS

Waste Disposal Methods: Material for disposal should be placed in appropriate sealed containers to avoid potential human and environmental exposure. It is the responsibility of the generator to comply with all federal, state, provincial and local laws and regulations. We recommend that you contact an appropriate waste disposal contractor and environmental agency for relevant laws and regulations. Under the U.S., Resource Conservation and Recovery Act (RCRA), it is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification.

Section 14: TRANSPORT INFORMATION

DOT:

Proper Shipping Name..... Not regulated
Hazard Class..... Not regulated
Identification Number..... Not regulated
Packing Group..... Not regulated
Label Required..... None

Section 15: REGULATORY INFORMATION

SARA Title III:

Section 302/304 Extremely Hazardous Substance:
None

Section 311 Hazardous Categorization:
None

Section 313 Toxic Chemicals:
None

CERCLA Section 102(a) Hazardous Substance:
None

RCRA Information:

Currently, the product is not listed in federal hazardous waste regulations 40 CFR, Part 261.33, paragraphs (e) or (f), i.e. chemical products that are considered hazardous if they become wastes. State or local hazardous waste regulations may also apply if they are different from the federal regulation. It is the responsibility of the user of the product to determine at the time of disposal, whether the product meets relevant waste classification and to assure proper disposal.

WHMIS (Canada):

Classification:
None

This product has been classified in accordance with hazard criteria of the "Controlled Products Regulations" and this MSDS contains all the information required by the "Controlled Products Regulations."

Ingredient Disclosure List:
None

Section 15: REGULATORY INFORMATION (Continued)

California Safe Drinking Water and Toxic Enforcement Act of 1986 (Proposition 65): Warning! The state of California has determined that the following listed component chemicals in this product may cause cancer, birth defects or other reproductive harm:
None

U.S., EPA, TSCA Information: This product is an article as defined by TSCA and is not required to be listed in the TSCA inventory.

Ozone Depletion Information: This product does not contain or is not manufactured with ozone depleting substances as identified in Title VI, Clean Air Act "Stratospheric Ozone Protection" and the regulations set forth in 40 CFR, Part 82.

Section 16: OTHER INFORMATION

Special Precautions: Airborne carbon fibers or dust are electrically conductive and may create electrical short-circuits that could result in damage to and malfunction of electrical equipment and/or personal injury.

Explanation and Disclaimer: Wherever such words or phrases as "hazardous," "toxic," "carcinogen," etc. appear herein, they are used as defined or described under state employee right-to-know laws, Federal OSHA laws or the direct sources for these laws such as the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), etc. The use of such words or phrases should not be taken to mean that we deem or imply any substance or exposure to be toxic, hazardous or otherwise harmful. Any exposure can only be understood within the entire context of its occurrence, which includes such factors as the substance's characteristics as defined in the MSDS, amount and duration of exposures, other chemicals present and preexisting individual differences in response to the exposure.

The data provided in this MSDS is based on the information received from our raw material suppliers and other sources believed to be reliable. We are supplying you this data solely in compliance with the Federal OSHA Hazard Communication Standard, 29 CFR 1910.1200 and other Federal and state laws as described in Section 15: Regulatory Information.

The information contained in this MSDS is proprietary and confidential to Hexcel Corporation. This MSDS and the information in it are not to be used for purposes other than compliance with the Federal OSHA Hazard Communication Standard. If you have received this MSDS from any source other than Hexcel Corporation or its authorized agent, the information contained in it may have been modified from the original document and it may not be the most current revision.

Liability, if any, for use of this product is limited to the terms contained in our sale terms and conditions. We do not in any way warrant (expressed or implied, including any implied warranty for merchantability or fitness for a particular purpose) the data contained or the product described in this MSDS. Additionally, we do not warrant that the product will not infringe any patent or other proprietary or property rights of others.

Contact: David M. Rubin,
Hexcel Schwebel Environmental, Health and Safety Manager

Material Safety Data Sheet



Revision Number: 001.2

Issue date: 07/10/2013

1. PRODUCT AND COMPANY IDENTIFICATION

Product name:	Loctite Epoxy Heavy Duty Resin	IDH number:	1071248
Product type:	2-Component epoxy adhesive	Region:	United States
Company address:	Contact information: Telephone: 800.624.7767 MEDICAL EMERGENCY Phone: Poison Control Center 1-877-671-4608 (toll free) or 1-303-592-1711 TRANSPORT EMERGENCY Phone: CHEMTREC 1-800-424-9300 (toll free) or 1-703-527-3887 Internet: www.henkelna.com		
Henkel Corporation One Henkel Way Rocky Hill, Connecticut 06067			

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Physical state:	Liquid	HEALTH:	2
Color:	Translucent, Clear	FLAMMABILITY:	1
Odor:	None	PHYSICAL HAZARD:	0
		Personal Protection:	See MSDS Section 8

WARNING: MAY CAUSE ALLERGIC SKIN REACTION.
MAY CAUSE EYE AND RESPIRATORY TRACT IRRITATION.

Relevant routes of exposure: Skin, Inhalation, Eyes

Potential Health Effects

Inhalation:	Mild respiratory tract irritation.
Skin contact:	Allergic skin reaction. Moderate skin irritation. Itching. Redness.
Eye contact:	Moderate eye irritation. Redness.
Ingestion:	Not expected under normal conditions of use.

Existing conditions aggravated by exposure: Skin disorders. Skin allergies.

This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

See Section 11 for additional toxicological information.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous components	CAS NUMBER	%
Epichlorohydrin-4,4'-Isopropylidene diphenol resin	25068-38-6	> 90

4. FIRST AID MEASURES

Inhalation:	Move to fresh air. If symptoms develop and persist, get medical attention.
Skin contact:	Immediately flush skin with plenty of water (using soap, if available). Remove contaminated clothes. If symptoms develop and persist, get medical attention.
Eye contact:	In case of contact with the eyes, rinse immediately with plenty of water for 15 minutes, and seek immediate medical attention.

IDH number: 1071248

Page 1 of 4

Product name: Loctite Epoxy Heavy Duty Resin

Ingestion: Keep individual calm. DO NOT induce vomiting unless directed to do so by medical personnel. If symptoms develop and persist, get medical attention.

5. FIRE FIGHTING MEASURES

Flash point: > 249 °C (> 480.2 °F) Pensky Martens closed cup

Autoignition temperature: Not available.

Flammable/Explosive limits - lower: Not available.

Flammable/Explosive limits - upper: Not available.

Extinguishing media: Foam, dry chemical or carbon dioxide.

Special firefighting procedures: Wear self-contained breathing apparatus and full protective clothing, such as turn-out gear.

Unusual fire or explosion hazards: In case of fire, keep containers cool with water spray. Closed containers may rupture (due to build up of pressure) when exposed to extreme heat.

Hazardous combustion products: Oxides of carbon. Irritating organic fragments.

6. ACCIDENTAL RELEASE MEASURES

Use personal protection recommended in Section 8, isolate the hazard area and deny entry to unnecessary and unprotected personnel.

Environmental precautions: Do not allow product to enter sewer or waterways.

Clean-up methods: Remove all sources of ignition. Immediately contact emergency personnel. Scrape up as much material as possible. Clean residue with soap and water. Store in a partly filled, closed container until disposal.

7. HANDLING AND STORAGE

Handling: Do not breathe gas/fumes/vapor/spray. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling. Keep container closed.

Storage: Store in original container until ready to use. Keep in a cool, well ventilated area away from heat, sparks and open flame. Keep container tightly closed until ready for use.

For information on product shelf life contact Henkel Customer Service at (800) 243-4874.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Employers should complete an assessment of all workplaces to determine the need for, and selection of, proper exposure controls and protective equipment for each task performed.

Hazardous components	ACGIH TLV	OSHA PEL	AIHA WEEL	OTHER
Epichlorohydrin-4,4'-isopropylidene diphenol resin	None	None	None	None

Engineering controls: Provide adequate local exhaust ventilation to maintain worker exposure below exposure limits.

Respiratory protection: Use a NIOSH approved air-purifying respirator if the potential to exceed established exposure limits exists.

Eye/face protection: Safety goggles or safety glasses with side shields.

Skin protection: Chemical resistant, impermeable gloves.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	Liquid
Color:	Translucent, Clear
Odor:	None
Odor threshold:	Not available.
pH:	Not available.
Vapor pressure:	0.03 mm hg
Boiling point/range:	> 260.2 °C (> 500.4 °F)
Melting point/ range:	Not available.
Specific gravity:	1.17
Vapor density:	Not available.
Flash point:	> 249 °C (> 480.2 °F) Pensky Martens closed cup
Flammable/Explosive limits - lower:	Not available.
Flammable/Explosive limits - upper:	Not available.
Autoignition temperature:	Not available.
Evaporation rate:	Not available.
Solubility in water:	Slight
Partition coefficient (n-octanol/water):	Not available.
VOC content:	0.10 % (value for resin and hardener together)

10. STABILITY AND REACTIVITY

Stability:	Stable
Hazardous reactions:	Will not occur.
Hazardous decomposition products:	None
Incompatible materials:	Strong oxidizing agents. Strong bases. Strong acids. Amines.
Conditions to avoid:	Excessive heat. Store away from incompatible materials.

11. TOXICOLOGICAL INFORMATION

Hazardous components	NTP Carcinogen	IARC Carcinogen	OSHA Carcinogen (Specifically Regulated)
Epichlorohydrin-4,4'-isopropylidene diphenol resin	No	No	No

Hazardous components	Health Effects/Target Organs
Epichlorohydrin-4,4'-isopropylidene diphenol resin	Allergen, Irritant

12. ECOLOGICAL INFORMATION

Ecological Information:	Not available.
-------------------------	----------------

13. DISPOSAL CONSIDERATIONS

Information provided is for unused product only.

Recommended method of disposal:	Follow all local, state, federal and provincial regulations for disposal.
Hazardous waste number:	Not a RCRA hazardous waste.

14. TRANSPORT INFORMATION

U.S. Department of Transportation Ground (49 CFR)

Proper shipping name:	Not regulated
Hazard class or division:	None
Identification number:	None
Packing group:	None

International Air Transportation (ICAO/IATA)

Proper shipping name: Environmentally hazardous substance, liquid, n.o.s. (Bisphenol-A Epichlorhydrin resin)
Hazard class or division: 9
Identification number: UN 3082
Packing group: III

Water Transportation (IMO/MDG)

Proper shipping name: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S. (Bisphenol-A Epichlorhydrin resin)
Hazard class or division: 9
Identification number: UN 3082
Packing group: III
Marine pollutant: Bisphenol-A Epichlorhydrin resin

15. REGULATORY INFORMATION**United States Regulatory Information**

TSCA 8 (b) Inventory Status: All components are listed or are exempt from listing on the Toxic Substances Control Act Inventory.
TSCA 12(b) Export Notification: None above reporting de minimis
CERCLA/SARA Section 302 EHS: None above reporting de minimis
CERCLA/SARA Section 311/312: Not available.
CERCLA/SARA 313: None above reporting de minimis
California Proposition 65: This product contains a chemical known in the State of California to cause cancer. This product contains a chemical known to the State of California to cause birth defects or other reproductive harm.

Canada Regulatory Information

CEPA DSL/NDSL Status: All components are listed on or are exempt from listing on the Canadian Domestic Substances List.

16. OTHER INFORMATION

This material safety data sheet contains changes from the previous version in sections: Not available.

Prepared by: Donna Houston, Regulatory Affairs Specialist

DISCLAIMER: The data contained herein are furnished for information only and are believed to be reliable. However, Henkel Corporation and its affiliates ("Henkel") does not assume responsibility for any results obtained by persons over whose methods Henkel has no control. It is the user's responsibility to determine the suitability of Henkel's products or any production methods mentioned herein for a particular purpose, and to adopt such precautions as may be advisable for the protection of property and persons against any hazards that may be involved in the handling and use of any Henkel's products. In light of the foregoing, Henkel specifically disclaims all warranties, express or implied, including warranties of merchantability and fitness for a particular purpose, arising from sale or use of Henkel's products. Henkel further disclaims any liability for consequential or incidental damages of any kind, including lost profits.

Material Safety Data Sheet



Revision Number: 004.0

Issue date: 12/27/2011

1. PRODUCT AND COMPANY IDENTIFICATION

Product name:	Loctite Epoxy Heavy Duty Hardener	IDH number:	1137985
Product type:	Epoxy Hardener	Item number:	193468
		Region:	United States
Company address:	Contact Information:		
Henkel Corporation	Telephone: 860.571.5100		
One Henkel Way	MEDICAL EMERGENCY Phone: Polson Control Center		
Rocky Hill, Connecticut 06067	1-877-671-4608 (toll free) or 1-303-592-1711		
	TRANSPORT EMERGENCY Phone: CHEMTREC		
	1-800-424-9300 (toll free) or 1-703-527-3887		
	Internet: www.henkelna.com		

2. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

Physical state:	Liquid	HEALTH:	3
Color:	Amber, Clear	FLAMMABILITY:	1
Odor:	Amine, Mercaptan	PHYSICAL HAZARD:	1
		Personal Protection:	See MSDS Section 8

DANGER: CAUSES EYE, SKIN AND RESPIRATORY TRACT BURNS.
MAY CAUSE ALLERGIC SKIN REACTION.
HARMFUL IF SWALLOWED OR ABSORBED THROUGH SKIN.

Relevant routes of exposure: Skin, Inhalation, Eyes, Ingestion

Potential Health Effects

Inhalation:	Respiratory tract burns. May cause respiratory tract irritation. May cause irritation to nose and throat. Lung damage.
Skin contact:	May cause skin burns. Allergic skin reaction. May be harmful if absorbed through skin. Rash. Redness. Tissue damage.
Eye contact:	Burns. Severe eye irritation. Redness. Tissue damage.
Ingestion:	May be harmful if swallowed. May cause burns of mouth and throat if swallowed.

Existing conditions aggravated by exposure: Eye, skin, and respiratory disorders. Skin allergies.

This material is considered hazardous by the OSHA Hazard Communication Standard (29 CFR 1910.1200).

See Section 11 for additional toxicological information.

3. COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous components	CAS NUMBER	%
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptan	72244-98-5	60 - 100
N-Aminoethylpiperazine	140-31-8	5 - 10
Aliphatic Amines	Unknown	5 - 10
2,4,6-Tris(dimethylaminomethyl)phenol	90-72-2	5 - 10
Silica, amorphous, fumed, crystal-free	112945-52-5	1 - 5

IDH number: 1137985

Page 1 of 5

Product name: Loctite Epoxy Heavy Duty Hardener

4. FIRST AID MEASURES

Inhalation:	Move to fresh air. If breathing is difficult, give oxygen. If not breathing, give artificial respiration. If symptoms develop and persist, get medical attention.
Skin contact:	Immediately flush skin with plenty of water (using soap, if available). Remove contaminated clothing and footwear. Wash clothing before reuse. Thoroughly clean shoes before reuse. If symptoms develop and persist, get medical attention.
Eye contact:	Immediately flush eyes with plenty of water for at least 15 minutes. Get medical attention.
Ingestion:	DO NOT induce vomiting unless directed to do so by medical personnel. Keep individual calm. Get medical attention.

5. FIRE FIGHTING MEASURES

Flash point:	> 93 °C (> 199.4 °F) Tagliabue closed cup
Autoignition temperature:	Not available.
Flammable/Explosive limits - lower:	Not available.
Flammable/Explosive limits - upper:	Not available.
Extinguishing media:	Water spray (fog), foam, dry chemical or carbon dioxide.
Special firefighting procedures:	Wear self-contained breathing apparatus and full protective clothing, such as turn-out gear.
Unusual fire or explosion hazards:	In case of fire, keep containers cool with water spray.
Hazardous combustion products:	Oxides of carbon. Oxides of nitrogen. Ammonia. Amines. Nitric acid. Nitrosamines. Irritating organic fragments.

6. ACCIDENTAL RELEASE MEASURES

Use personal protection recommended in Section 8, isolate the hazard area and deny entry to unnecessary and unprotected personnel.	
Environmental precautions:	Do not empty into drains / surface water / ground water.
Clean-up methods:	Remove all sources of ignition. Store in a closed container until ready for disposal. Immediately contact emergency personnel. Scrape up as much material as possible. Clean residue with soap and water.

7. HANDLING AND STORAGE

Handling:	Keep away from heat, spark and flame. Keep container closed. Avoid breathing vapors or mists of this product. Avoid contact with eyes, skin and clothing. Wash thoroughly after handling.
Storage:	For safe storage, store at or below 37.8 °C (100°F). Store in original container until ready to use. Keep in a cool, well ventilated area away from heat, sparks and open flame. Keep container tightly closed until ready for use.

For information on product shelf life contact Henkel Customer Service at (800) 243-4874.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Employers should complete an assessment of all workplaces to determine the need for, and selection of, proper exposure controls and protective equipment for each task performed.

Hazardous components	ACGIH TLV	OSHA PEL	AIHA WEEL	OTHER
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptan	None	None	None	None
N-Aminoethylpiperazine	None	None	None	None
Aliphatic Amines	None	None	None	None
2,4,6-Tris(dimethylaminomethyl)phenol	None	None	None	None
Silica, amorphous, fumed, crystal-free	10 mg/m3 TWA Inhalable dust. 3 mg/m3 TWA Respirable fraction.	20 MPPCF TWA 0.8 mg/m3 TWA	None	None

Engineering controls:	Use local ventilation if general ventilation is insufficient to maintain vapor concentration below established exposure limits.
Respiratory protection:	Use a NIOSH approved air-purifying respirator if the potential to exceed established exposure limits exists.
Eyel/face protection:	Safety goggles or safety glasses with side shields.
Skin protection:	Chemical resistant, impermeable gloves.

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical state:	Liquid
Color:	Amber, Clear
Odor:	Amine, Mercaptan
Odor threshold:	Not available.
pH:	Not available.
Vapor pressure:	Not available.
Boiling point/range:	Not available.
Melting point/ range:	Not available.
Specific gravity:	1.04
Vapor density:	Not available.
Flash point:	> 93 °C (> 199.4 °F) Tagliabue closed cup
Flammable/Explosive limits - lower:	Not available.
Flammable/Explosive limits - upper:	Not available.
Autoignition temperature:	Not available.
Evaporation rate:	Not available.
Solubility in water:	Slightly soluble
Partition coefficient (n-octanol/water):	Not available.
VOC content:	0.38 %; 3.7 g/l EPA Method 24

10. STABILITY AND REACTIVITY

Stability:	Stable
Hazardous reactions:	Will not occur.
Hazardous decomposition products:	None
Incompatible materials:	Strong acids. Strong oxidizing agents. Halogenated compounds. Strong mineral acids. Reactive metals. Calcium hypochlorite. Sodium hypochlorite. Nitrous acid and other nitrosating agents.
Conditions to avoid:	Excessive heat. Store away from incompatible materials.

11. TOXICOLOGICAL INFORMATION

Hazardous components	NTP Carcinogen	IARC Carcinogen	OSHA Carcinogen (Specifically Regulated)
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptan	No	No	No
N-Aminoethylpiperazine	No	No	No
Aliphatic Amines	No	No	No
2,4,6-Tris(dimethylaminomethyl)phenol	No	No	No
Silica, amorphous, fumed, crystal-free	No	No	No

Hazardous components	Health Effects/Target Organs
Poly[oxy(methyl-1,2-ethanediyl)], a-hydro-w-hydroxy-, ether with 2,2-bis(hydroxymethyl)-1,3-propanediol (4:1), 2-hydroxy-3-mercaptan	No Records
N-Aminoethylpiperazine	Irritant, Corrosive, Allergen
Aliphatic Amines	No Data
2,4,6-Tris(dimethylaminomethyl)phenol	Irritant, Allergen
Silica, amorphous, fumed, crystal-free	Nuisance dust

12. ECOLOGICAL INFORMATION

Ecological information: Not available.

13. DISPOSAL CONSIDERATIONS

Information provided is for unused product only.

Recommended method of disposal: Follow all local, state, federal and provincial regulations for disposal.

Hazardous waste number: Not a RCRA hazardous waste.

14. TRANSPORT INFORMATION

U.S. Department of Transportation Ground (49 CFR)

Proper shipping name: Amines, liquid, corrosive, n.o.s. (Aminoethylpiperazine, Aliphatic amines)
Hazard class or division: 8
Identification number: UN 2735
Packing group: II

International Air Transportation (ICAO/IATA)

Proper shipping name: Amines, liquid, corrosive, n.o.s. (Aminoethylpiperazine, Aliphatic amines)
Hazard class or division: 8
Identification number: UN 2735
Packing group: II

Water Transportation (IMO/IMDG)

Proper shipping name: AMINES, LIQUID, CORROSIVE, N.O.S. (Aminoethylpiperazine, Aliphatic amines)
Hazard class or division: 8
Identification number: UN 2735
Packing group: II

15. REGULATORY INFORMATION

United States Regulatory Information

TSCA 8 (b) Inventory Status: All components are listed or are exempt from listing on the Toxic Substances Control Act Inventory.
TSCA 12(b) Export Notification: None above reporting de minimus

CERCLA/§ARA Section 302 EHS:	None above reporting de minimus
CERCLA/§ARA Section 311/312:	Immediate Health
CERCLA/§ARA 313:	None above reporting de minimus
California Proposition 65:	No California Proposition 65 listed chemicals are known to be present.

Canada Regulatory Information

CEPA DSL/NDSL Status:	All components are listed on or are exempt from listing on the Canadian Domestic Substances List.
WHMIS hazard class:	D.2.B, E

16. OTHER INFORMATION

This material safety data sheet contains changes from the previous version in sections: New Material Safety Data Sheet format.

Prepared by: Gary Pierson, Manager, Regulatory Affairs

DISCLAIMER: The data contained herein are furnished for information only and are believed to be reliable. However, Henkel Corporation and its affiliates ("Henkel") does not assume responsibility for any results obtained by persons over whose methods Henkel has no control. It is the user's responsibility to determine the suitability of Henkel's products or any production methods mentioned herein for a particular purpose, and to adopt such precautions as may be advisable for the protection of property and persons against any hazards that may be involved in the handling and use of any Henkel's products. In light of the foregoing, Henkel specifically disclaims all warranties, express or implied, including warranties of merchantability and fitness for a particular purpose, arising from sale or use of Henkel's products. Henkel further disclaims any liability for consequential or incidental damages of any kind, including lost profits.

=====

MATERIAL SAFETY DATA SHEET

=====

ProX Rocket Motor Reload Kits & Fuel Grains

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: Pro29, Pro38, Pro54, Pro75, and Pro98 Rocket Motor Reload Kits
Synonyms: Rocket Motor
Proper Shipping Name: Articles, Explosive, N.O.S. (Ammonium Perchlorate)
Part Numbers: Reload kits: P29R-Y-#G-XX, P38R-Y-#G-XX, P54R-Y-#G-XX,
P29R-Y-#GXL-XX, P38R-Y-#GXL-XX, P54R-Y-#GXL-XX,
P75AC-PG-XX, P98AC-PG-XX, P98AC-MB-PG-XX
Propellant grains: Where: Y = reload type (A = adjustable delay, C = C-slot)
= number of grains &
XX = propellant type

Product Use: Solid fuel motor for propelling rockets

Manufacturer: Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, Ont.
Canada L0H 1G0

Telephone Numbers:
Product Information: 1-905-887-2370
24 Hour Emergency Telephone Number: 1-613-996-6666 (CANUTEC)

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Propellant

Ingredient Name	CAS Number	Percentage
Ammonium Perchlorate	7790-98-9	40-85 %
Metal Powders		1-45 %
Synthetic Rubber		10-30 %

Black Powder Ignition pellet

Ingredient Name	CAS Number	Percentage
Potassium Nitrate	7757-79-1	70-76 %
Charcoal	n/a	8-18 %
Sulphur	7704-34-9	9-20 %
Graphite	7782-42-5	trace

3.0 HAZARDS IDENTIFICATION

Emergency Overview:

These articles contain cylinders of ammonium perchlorate composite propellant, encased in inert plastic parts. The forward closure also contains a few grams of black powder. ProX Rocket motor reload kits are classified as explosives, and may cause serious injury, including death if used improperly. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced personnel in accordance with all applicable federal, state and local laws and regulations. Avoid inhaling exhaust products.

General Appearance:

Cardboard tubes contain various plastic parts. Inside the plastic tube are cylinders of composite propellant (rocket fuel). The forward closure also contains a small quantity of black powder. All parts are odourless solids.

Potential Health Effects:**Eye:**

Not a likely route of exposure. May cause eye irritation.

Skin:

Not a likely route of exposure. Low hazard for usual industrial/hobby handling.

Ingestion:

Not a likely route of exposure.

Inhalation:

Not a likely route of exposure. May cause respiratory tract irritation. Do not inhale exhaust products.

4.0 FIRST AID MEASURES

Eyes:

Immediately flush eyes with plenty of water for at least 15 minutes, occasionally lifting the upper and lower eyelids. Get medical aid.

Skin:

Flush skin with plenty of soap and water for at least 15 minutes while removing contaminated clothing and shoes. Get medical aid if irritation develops or persists.

Ingestion:

Do NOT induce vomiting. If conscious and alert, rinse mouth and drink 2-4 cups of milk or water.

Inhalation:

Remove from exposure to fresh air immediately. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical aid.

Burns: Burns can be treated as per normal first aid procedures.

5.0 FIRE FIGHTING MEASURES

Extinguishing Media:

In case of fire, use water, dry chemical, chemical foam, or alcohol-resistant foam to contain surrounding fire.

Exposure Hazards During Fire:

Exposure to extreme heat may cause ignition.

Combustion Products from Fire:

During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion.

Fire Fighting Procedures:

Keep all persons and hazardous materials away. Allow material to burn itself out. As in any fire, wear a self-contained breathing apparatus in pressure-demand, MSHA/NIOSH (approved or equivalent), and full protective gear.

Special Instructions / Notes:

These articles burn rapidly and generate a significant flame for a short period of time. Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement. Do not inhale exhaust products.

6.0 ACCIDENTAL RELEASE MEASURES

Safeguards (Personnel):

Spills: Clean up spills immediately. Replace articles in packaging and boxes and seal securely. Sweep or scoop up using non-sparking tools.

7.0 HANDLING AND STORAGE

Handling:

Keep away from heat, sparks and flame. Avoid contamination. Do not get in eyes, on skin or on clothing. Do not taste or swallow. Avoid prolonged or repeated contact with skin. Follow manufacturer's instructions for use.

Storage: Store in a cool, dry place away from sources of heat, spark or flame. Keep in shipping packaging when not in use.

8.0 EXPOSURE CONTROLS / PERSONAL PROTECTION

Engineering Controls:

Use adequate explosion proof ventilation to keep airborne concentrations low. All equipment and working surfaces must be grounded.

Personal Protective Equipment:

Eyes:

Wear appropriate protective eyeglasses or chemical safety goggles as described by OSHA's eye and face protection regulations in 29 CFR 1910.133 or European Standard EN166.

Skin:

Clothing should be appropriate for handling pyrotechnic substances.

Clothing:

Clothing should be appropriate for handling pyrotechnic substances.

Respirators:

A respirator is not typically necessary. Follow the OSHA respirator regulations found in 29CFR1910.134 or European Standard EN 149. Always use a NIOSH or European Standard EN 149 approved respirator when necessary.

9.0 PHYSICAL AND CHEMICAL PROPERTIES

Physical State:	solid
Appearance:	rubber cylinders inside plastic parts
Odour:	none
Odour Threshold:	Not available.
pH:	Not available.
Vapour Pressure:	Not available.
Vapour Density:	Not available.
Viscosity:	Not available.
Evaporation Rate:	Not available.
Boiling Point:	Not available.
Freezing/Melting Point:	Not available.
Coefficient of water/oil distribution:	Not available.
Autoignition Temperature:	280°C
Flash Point:	Not available.
Explosion Limits, lower (LEL):	Not available.
Explosion Limits, upper (UEL):	Not available.
Sensitivity to Mechanical Impact:	unprotected black powder can be ignited by impact
Sensitivity to Static Discharge:	unprotected black powder can be ignited by static discharge
Decomposition Temperature:	> 400°C
Solubility in water:	black powder is soluble in water
Specific Gravity/Density:	black powder = 1.7-2.1 Propellant = not available
Molecular Formula:	Not applicable
Molecular Weight:	Not applicable.

10.0 STABILITY AND REACTIVITY

Chemical Stability:

Stable under normal temperatures and pressures.

Conditions to Avoid:

Heat, static electricity, friction, impact

Incompatibilities with Other Materials:

Combustible or flammable materials, explosive materials

Hazardous Products Of Decomposition:

Oxides of nitrogen

Hazardous Polymerization:

Will not occur.

11.0 TOXICOLOGICAL INFORMATION

Routes of Entry: Skin contact – not likely
 Skin absorption – not likely
 Eye contact – not likely
 Inhalation – not likely
 Ingestion – not likely

Effects of Acute Exposure to Product:

No data available

Effects of Chronic Exposure to Product:

No data available

Exposure Limits:

Black Powder Pellets

Ingredient Name	CAS Number	OSHA PEL	ACGIH TLV
Potassium Nitrate	7757-79-1	not established	not established
Charcoal	n/a	not established	not established
Sulphur	7704-34-9	not established	not established
Graphite	7782-42-5	2.5 mg/m ³	15 mmpt (TWA)

Propellant

Ingredient Name	CAS Number	OSHA PEL	ACGIH TLV
Ammonium Perchlorate	7790-98-9	not established	not established
metal powder		varies	varies
Synthetic Rubber		not established	not established

Irritancy of the Product:

No data available

Sensitization to the Product:

No data available

Carcinogenicity:

Not listed by ACGIH, IARC, NIOSH, NTP, or OSHA

Reproductive Toxicity:

No data available

Teratogenicity:

No data available

Mutagenicity:

No data available

Toxically Synergistic Products:

No data available

LD50:

No data available

12.0 ECOLOGICAL INFORMATION

Environmental Data:

Ecotoxicity Data:

Not determined.

EcoFaTE Data:

Not determined.

13.0 DISPOSAL CONSIDERATIONS

Product As Sold:

Pack firmly in hole in ground with nozzle pointing up. Ignite motor electrically from a safe distance and wait 5 minutes before approaching. Dispose of spent components in inert trash.

Product Packaging:

Dispose of used packaging materials in inert trash.

Special Considerations:

Consult local regulations about disposal of explosive materials.

14.0 TRANSPORT INFORMATION

Shipping Information – Canada

TDG Classification:	Class 1.4 Explosive
Proper Shipping Name:	Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number:	0351
UN Classification Code:	1.4 C
Packing Group:	II
UN Packing Instruction:	101

Shipping Information - USA / IMO

Proper Shipping Name:	Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number:	0351
UN Classification Code:	1.4 C
DOT / IMO Label:	Class 1 – Explosive – Division 1.4C

Shipping Information - IATA

Proper Shipping Name:	Articles, Explosive, N.O.S. (Model Rocket Motors)
UN Number:	0351
UN Classification Code:	1.4 C
IATA Labels:	Class 1 – Explosive – Division 1.4C Cargo Aircraft Only

15.0 REGULATORY INFORMATION

Canada

This product has been classified according to the hazard criteria of the Canadian Controlled Products Regulations (CPR) and the MSDS contains all of the information required by the CPR.

WHMIS Classification:	Not Controlled (explosive)
------------------------------	----------------------------

Domestic Substance List (DSL) Status:
All ingredients are listed on Canada's DSL List.

Canadian Explosives Classification: Class 7.2.5
This product is an authorized explosive in Canada.

These products are not considered "Controlled Good" in Canada under the Controlled Goods Regulations.

United States of America

TSCA Inventory Status:
All ingredients are listed on the TSCA Inventory.

Hazardous Chemical Lists	
CERCLA Hazardous Substance (40 CFR 302.4)	No
SARA Extremely Hazardous Substance (40CFR 355)	No
SARA Toxic Chemical (40CFR 372.65)	No

European/International Regulations

The product on this MSDS, or all its components, is included on the following countries' chemical inventories:
EINECS – European Inventory of Existing Commercial Chemical Substances

European Labelling in Accordance with EC Directives

Hazard Symbols: Explosive.

Risk Phrases:

R 2	Risk of explosion by shock, friction, fire or other sources of ignition.
R 11	Highly flammable
R 44	Risk of explosion if heated under confinement.

Safety Phrases:

S 1/2	Keep locked up and out of the reach of children.
S 8	Keep container dry.
S 15	Keep away from heat.
S 16	Keep away from sources of ignition – No smoking.

- § 17 Keep away from combustible material.
§ 18 Handle and open container with care.
§ 33 Take precautionary measures against static discharges.
§ 41 In case of fire and/or explosion do not breathe fumes.

16.0 OTHER INFORMATION

MSDS Prepared by: Regulatory Affairs Department
Cesaroni Technology Inc.
P.O. Box 246
2561 Stouffville Rd.
Gormley, ON
Canada L0H 1G0

Telephone: 905-887-2370 x239
Fax: 905-887-2375
Web Sites: www.cesaronitech.com
www.Pro38.com

The data in this Material Safety Data Sheet relates only to the specific material or product designated herein and does not relate to use in combination with any other material or in any process.

The information above is believed to be accurate and represents the best information currently available to us. However, we make no warranty of merchantability or any other warranty, express or implied, with respect to such information, and we assume no liability resulting from its use. Users should make their own investigations to determine the suitability of the information for their particular purposes. In no way shall the company be liable for any claims, losses, or damages of any third party or for lost profits or any special, indirect, incidental, consequential or exemplary damages, howsoever arising, even if the company has been advised of the possibility of such damages.



Goex Powder, Inc.

Material Safety Data Sheet

MSDS-BP (Potassium Nitrate)

Revised 3/17/09

PRODUCT INFORMATION	
Product Name	Black Powder
Trade Names and Synonyms	N/A
Manufacturer/Distributor	GOEX Powder, Inc. (DOYLINE, LA) & various international sources
Transportation Emergency	800-255-3924 (24 hrs – CHEM TEL)

PREVENTION OF ACCIDENTS IN THE USE OF EXPLOSIVES

The prevention of accidents in the use of explosives is a result of careful planning and observance of the best known practices. The explosives user must remember that he is dealing with a powerful force and that various devices and methods have been developed to assist him in directing this force. He should realize that this force, if misdirected, may either kill or injure both him and his fellow workers.

WARNING

All explosives are dangerous and must be carefully transported, handled, stored, and used following proper safety procedures either by or under the direction of competent, experienced persons in accordance with all applicable federal, state and local laws, regulations, or ordinances. ALWAYS lock up explosive materials and keep away from children and unauthorized persons. If you have any questions or doubts as to how to use any explosive product, DO NOT USE IT before consulting with your supervisor, or the manufacturer, if you do not have a supervisor. If your supervisor has any questions or doubts, he should consult the manufacturer before use.

HAZARDOUS COMPONENTS				
Material or Components	%	CAS NO.	TLV	PEL
Potassium nitrate	70-76	007757-79-1	NE	NE
Charcoal	8-18	N/A	NE	NE
Sulfur	9-20	007704-34-9	NE	NE
Graphite ¹	Trace	007782-42-5	15 mppt (TWA)	2.5 mg/m ³

N/A = Not assigned NE = Not established

¹ Not contained in all grades of black powder.

PHYSICAL DATA	
Boiling Point	N/A
Vapor Pressure	N/A
Vapor Density	N/A
Solubility in Water	Good
Specific Gravity	1.70 – 1.82 (mercury method) 1.92 – 2.08 (pycnometer)
PH	6.0 – 8.0
Evaporation Rate	N/A
Appearance and Odor	Black granular powder. No odor detectable.

HAZARDOUS REACTIVITY	
Instability	Keep away from heat, sparks, and open flames. Avoid impact, friction and static electricity.
Incompatibility	When dry, black powder is compatible with most metals; however, it is hygroscopic and when wet, attacks all common metals except stainless steel. Black powder must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials, and other similar materials, situations, and equipment.
Hazardous decomposition	Detonation produces hazardous overpressures and fragments (if confined). Gases produced may be toxic if exposed in areas with inadequate ventilation.
Polymerization	Polymerization will not occur.

FIRE AND EXPLOSION DATA	
Flashpoint	Not applicable
Auto Ignition Temperature	Approx. Range: 392°F-867°F / 200°C-464°C
Explosive temperature (5 sec)	Ignites @ approx. 427°C (801°F)
Extinguishing media	Water
Special fire fighting procedures	ALL EXPLOSIVES: DO NOT FIGHT EXPLOSIVES FIRES. Try to keep fire from reaching explosives. Isolate area. Guard against intruders. Division 1.1 Explosives (heavily encased): Evacuate the area for 5,000 feet (approximately 1 mile) if explosives are heavily encased. Division 1.1 Explosives (not heavily encased): Evacuate the area for 2,500 feet (approximately ¼ mile) if explosives are not heavily encased. Division 1.1 Explosives (all): Consult U.S. DOT Emergency Response Guide 112 for further details.

Unusual fire and explosion hazards	Black powder is a deflagrating explosive. It is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.
------------------------------------	--

HEALTH HAZARDS

General	Black powder is a Division 1.1 Explosive, and detonation may cause severe physical injury, including death. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced persons in accordance with all applicable federal, state and local laws, regulation and ordinances.
Carcinogenicity	None of the components of Black Powder are listed as a carcinogen by NTP, IARC, or OSHA.

FIRST AID

Inhalation	Not a likely route of exposure. If inhaled, remove to fresh air. If not breathing give artificial respiration, preferably by mouth-to-mouth. If breathing is difficult, give oxygen. Seek prompt medical attention. Avoid when possible.
Eye and skin contact	Not a likely route of exposure. Flush eyes with water. Wash skin with soap and water.
Ingestion	Not a likely route of exposure. If ingested, dilute by giving two glasses of water and induce vomiting. Avoid when possible.
Injury from detonation	Seek prompt medical attention.

SPILL OR LEAK PROCEDURES

Spill/leak response	Use appropriate personal protective equipment. Isolate area and remove sources of friction, impact, heat, low level electrical current, electrostatic or RF energy. Only competent, experienced persons should be involved in clean up procedures. Carefully pick up spills with non-sparking and non-static producing tools.
Waste disposal	Desensitize by diluting in water. Open train burning, by qualified personnel, may be used for disposal of small unconfined quantities. Dispose of in compliance with Federal Regulations under the authority of the Resource Conservation and Recovery Act (40 CFR Parts 260-271).

SPECIAL PROTECTION INFORMATION

Ventilation	Use only with adequate ventilation. (If required)
Respiratory	None
Eye	None
Gloves	Impervious rubber gloves. (If required)
Other	Metal-free and/non-static producing clothes

SPECIAL PRECAUTIONS

- Keep away from friction, impact, and heat and open flame. Do not consume food, drink, or tobacco in areas where they may become contaminated with these materials.
- Contaminated equipment must be thoroughly water cleaned before attempting repairs.
- Use only non-spark producing tools.
- No smoking.

STORAGE CONDITIONS

Store in a cool, dry place in accordance with the requirements of Subpart K, ATF: Explosives Law and Regulations (27 CFR 55.201-55.219).

SHIPPING INFORMATION

Proper shipping name	Black Powder	
Hazard class	1.1D	
UN Number	UN0027	
DOT Label & Placard	DOT Label	EXPLOSIVES 1.1D
	DOT Placard	EXPLOSIVES 1.1
Alternate shipping	Limited quantities of GOEX black powder (1# cans only) may be transported as "Black powder for small arms – flammable solid" pursuant to U.S. Department of Transportation 49 CFR.	

The information contained in this Material Safety Data Sheet is based upon available data and believed to be correct; however, as such has been obtained from various sources, including the manufacturer, military and independent laboratories, it is given without warranty or representation that it is complete, accurate, and can be relied upon. GOEX, Incorporated, has not attempted to conceal in any manner the deleterious aspects of the product listed herein, but makes no warranty as to such. Further, GOEX, Incorporated, cannot anticipate nor control the many situations in which the product or this information may be used; there is no guarantee that the health and safety precautions suggested will be proper under all conditions. It is the sole responsibility of each user of the product to determine and comply with the requirements of all applicable laws and regulations regarding its use. This information is given solely for the purposes of safety to persons and property. Any other use of this information is expressly prohibited.

For further information contact: GOEX Powder, Incorporated
P. O. Box 659
Doyline, LA 71023-0659
Telephone Number: (318) 382-9300
Fax Number: (318) 382-9303

BLACK POWDER

FRICTION TEST

PA

Steel – Snaps

Fiber – Unaffected

IMPACT TEST

PA

16 Inches (10% Point)

ELECTROSTATIC DISCHARGE TEST

Bureau of Mines

0.8 Joules (Confined)

12.5 Joules Unconfined)

STABILITY

75° C International Heat Test – 0.31% Loss

Vacuum Stability – 0.5cc @ 100° C

BRISANCE – Sand Test 8 gm.

VELOCITY

In the open, trains of black powder burn very slowly, measurable in seconds per foot. Confined, as in steel pipe, speeds of explosions have been timed at values from 560 feet per second for very coarse granulations to 2,070 feet per second for the finer granulations. Confinement and granulation will affect the values.

CHEMICAL DECOMPOSITION

Use water to dissolve the potassium nitrate. By leeching out the potassium nitrate, the residue of sulfur and charcoal is non-explosive but combustible when dry – dispose separately.

SPECIAL REQUIREMENTS:

Black Powder is very sensitive to flame and spark and can also be ignited by friction and impact. When ignited unconfined, it burns with explosive violence and will explode if ignited under even slight confinement.

When dry, it is compatible with most metals. However, it is hygroscopic and when wet, attacks all common metals except stainless steel.

CAUTION: Explosives must be tested for compatibility with any material not specified in the production/procurement package with which they may come in contact. Materials include other explosives, solvents, adhesives, metals, plastics, paints, cleaning compounds, floor and table coverings, packing materials and other similar materials, situations and equipment. Explosives include propellants and pyrotechnics.

=====

MATERIAL SAFETY DATA SHEET

=====

ProFire Igniter

1.0 PRODUCT / COMPANY IDENTIFICATION

Product Name: ProFire Igniter
Synonyms: Igniter, Initiator
Proper Shipping Name: Igniters
Part Number: INI-150
Product Use: Igniter for solid fuel rocket motor

Manufacturer: Cesaroni Technology Inc.
P.O. Box 248
2561 Stouffville Rd.
Gormley, Ont.
Canada L0H 1G0

Telephone Numbers:
Product Information: 1-805-887-2370
24 Hour Emergency Telephone Number: 1-813-998-6666 (CANUTEC)

2.0 COMPOSITION / INFORMATION ON INGREDIENTS

Overdip composition

Ingredient Name	CAS Number	Percentage
Barium chromate.....	10294-40-3	31-32 %
Magnesium powder.....	7439-95-4	42-43 %
Viton fluoroelastomer.....	n/a	26-27 %

3.0 HAZARDS IDENTIFICATION

Emergency Overview:

The igniter functions by burning rapidly at high temperature, releasing hot gas and particles that ignite the propellant of a rocket motor when in close proximity. All explosives are dangerous and must be handled carefully and used following approved safety procedures under the direction of competent, experienced personnel in accordance with all applicable federal, state and local laws and regulations.

General Appearance:

Cardboard tubes containing one igniter. Igniter has coiled wire leads terminating in the ignition device itself. Ignition device consists of a small electrical initiator (fuse head) dipped in a rubbery, silver-grey composition. All parts are essentially odourless solids, though trace odors of process solvents may be present.

Potential Health Effects:

- Eye:** Not a likely route of exposure. May cause eye irritation.
- Skin:** Not a likely route of exposure. Low hazard for usual industrial handling.
- Ingestion:** Not a likely route of exposure.
- Inhalation:** Not a likely route of exposure. May cause respiratory tract irritation.

CARGROOM ® - RETAIL
 U S Chemical & Plastics
Alco Industries Companies
 600 Nova Drive SE
 Massillon, OH 44646
 PH 330-830-6000 - FAX 330-830-6005

For Chemical Emergency

CHEMTREC: 1-800-424-9300

SECTION I - IDENTIFICATION OF PRODUCT

PRODUCT NAME:	FIBERGLASS CLOTH
PRODUCT CODE:	77080
SYNONYM/CROSS REFERENCE:	Continuous Filament Fiberglass Woven Cloth
SCHEDULE B NUMBER:	7019.52.0000

SECTION II - HAZARDOUS INGREDIENTS

INGREDIENTS	WGT%	CAS #	TLV/PEL
Fibrous Glass	98-99.9%	65997-17-3	Respirable PEL 5 mg/m ³ Respirable ACGIH TLV 1 mg/m ³
Organic Bound Silanes	< 0.4 %	Supplier Trade Secret	N/Av

SECTION III - PHYSICAL DATA

APPEARANCE: White to off-white fibers
SPECIFIC GRAVITY: 2.5
VAPOR PRESSURE (mmHG): N/Av
BOILING POINT: N/E
VAPOR DENSITY: N/ap
EVAPORATION RATE (Ethyl Ether = 1): N/Av
VOLATILES BY WEIGHT: None
SOLUBILITY IN WATER: Insoluble
VOC: Grams/Liter = None
 Lbs/Gallon = None

SECTION IV - FIRE AND EXPLOSION DATA

FLASH POINT: Non-burning
LOWER FLAMMABLE LIMIT %: N/Av
UPPER FLAMMABLE LIMIT %: N/Av
FIRE EXTINGUISHING MEDIA: Carbon Dioxide, Dry Chemical, Foam
SPECIAL FIRE FIGHTING PROCEDURES: None known Use SCBA.
UNUSUAL FIRE AND EXPLOSION HAZARD: None known.

SECTION V - HEALTH HAZARD/TOXICOLOGICAL PROPERTIES

OVEREXPOSURE EFFECTS:

ACUTE EFFECTS:

EYES: Contact with eyes can cause irritation, redness, tearing, blurred vision, and/or swelling.
SKIN: Contact with skin can cause irritation, (minor itching, burning and/or redness), Dermatitis.
INHALATION: Inhalation of dust can cause respiratory tract and lung irritation.
INGESTION: Ingestion can cause gastrointestinal irritation, nausea. .

CHRONIC EFFECTS:

Overexposure to this material has apparently been known to cause the following effects in lab animals:
None known

CARCINOGEN: YES ☐ NO ☒
TERATOGEN: YES ☐ NO ☒
MUTAGEN: YES ☐ NO ☒

ROUTES OF EXPOSURE: inhalation, skin

FIRST AID:

INHALATION: If inhaled, remove victim from exposure to a well-ventilated area. Make them comfortably warm, but not hot. Use oxygen or artificial respiration as required. Consult a physician.
SKIN: For skin contact, wash promptly with soap and excess water.
EYES: For eye contact, flush promptly with excess water for at least fifteen minutes. Consult a physician.
INGESTION: If ingested, do not induce vomiting. Give victim a glass of water. Call a physician immediately.

SECTION VI - REACTIVITY DATA

STABILITY: Stable

CONDITIONS TO AVOID: None known

INCOMPATIBILITY MATERIALS TO AVOID: None known.

HAZARDOUS DECOMPOSITION PRODUCTS: None Known.

HAZARDOUS POLYMERIZATION: Will not occur.

SECTION VII - SPILL AND DISPOSAL PROCEDURE

SPILLS, LEAK OR RELEASE: Sweep up remains manually or mechanically.

WASTE DISPOSAL: Dispose of in accordance with local, state, and federal regulations.

SECTION VIII - PROTECTION INFORMATION

RESPIRATORY PROTECTION: If component TLV limits are exceeded, use NIOSH/MSHA approved respirator to remove contaminants.

VENTILATION: Use adequate ventilation in volume and pattern to keep TLV/PEL below recommended levels.

PROTECTIVE GLOVES: Use of gloves to prevent irritation.

EYE PROTECTION: Safety Glasses or goggles with splash guards or side shields.

OTHER PROTECTIVE EQUIPMENT: Wear protective clothing as required to prevent skin contact.

SECTION IX - HANDLING AND STORAGE PRECAUTIONS

STORAGE AND HANDLING: Use with adequate ventilation. Avoid contact with eyes and skin. Avoid breathing fibers.

SECTION X - ADDITIONAL INFORMATION

SHIPPING INFORMATION: Not regulated.

HMIS RATING:

Health	0	4 = Extreme
Fire	0	3 = High
Reactivity	0	2 = Moderate
		1 = Slight
		0 = Insignificant
Personal Protection - See Section VIII		

SECTION 313 SUPPLIER NOTIFICATION:

This product contains the following toxic chemicals subject to the reporting requirements of the Emergency Planning and Community Right-To-Know Act of 1986 and 40 CFR 372:

<u>CHEMICAL NAME</u>	<u>CAS</u>	<u>% BY WGT</u>
----------------------	------------	-----------------

Not Applicable

THIS INFORMATION MUST BE INCLUDED IN ALL MSDS'S THAT ARE COPIED AND DISTRIBUTED FOR THIS CHEMICAL

=====

ABBREVIATIONS

=====

IARC = International Agency for Research on Cancer
ACGIH = American Conference of Governmental Industrial Hygienists
NIOSH = National Institute of Occupational Safety and Health
TLV = Threshold Limit Value
PEL = Permissible Emission Level
DOT = Department of Transportation
NTP = National Toxicology Program
N/AV = Not Available
N/AP = Not Applicable
N/E = Not Established
N/D = Not Determined

PREPARED BY: U S CHEMICAL & PLASTICS
Alco Industries Companies
600 NOVA DRIVE SE
MASSILLON, OH 44646

TELEPHONE NBR 330-830-6000
FAX NBR 330-830-6005

DATE REVIEWED: September 14, 2012
DATE REVISED: September 14, 2012
REVISION: Sections I-II, VII-X

The information in the Material Safety Data Sheet has been compiled from our experience and from data presented in various technical publications. It is the user's responsibility to determine the suitability of this information for the adoption of the safety precautions as may be necessary. We reserve the right to revise Material Safety Data Sheets from time to time as new technical information becomes available. The user has the responsibility to contact the Company to make sure that the MSDS is the latest one issued.

MATERIAL SAFETY DATA SHEET

G-10

EFFECTIVE DATE	December 19, 1997
REVISED DATE	April 8, 2011
TRADE NAME	Industrial Laminate
CHEMICAL FAMILY	Cured Epoxy Resin and Glass
CHEMICAL FORMULA	Grade: G-10
SECTION II - HAZARDOUS INGREDIENTS	
HAZARDOUS COMPONENTS	Amine Curing Agent
	This product consists of cured epoxy resin on a glass substrate. TVL has not been established by the ACGIH.
SECTION III - PHYSICAL DATA	
BOILING POINT (F)	N/A
FREEZING POINT (F)	
VOLATILITY / VOLUME (%)	N/A
MELTING POINT	
VAPOR PRESSURE (mm-Hg)	Non-Volatile
VAPOR DENSITY (Air=1)	N/A
SOLUBILITY IN H2O	N/A
APPEARANCE / ODOR	Natural (yellowish green to green) with no odor.
SPECIFIC GRAVITY (H2O=1)	1.75 - 1.85
ACIDITY	
SECTION IV- FIRE AND EXPLOSION HAZARD DATA	
FLASH POINT	Non-Volatile
LOWER FLAME POINT	
HIGHER FLAME POINT	
EXTINGUISH MEDIA	Water CO2 or Foam
FOR FIRE	Appropriate respiratory equipment (atmosphere supplying should be used when entering a burning area.
UNUSUAL FIRE HAZARD	Carbon Monoxide may be released while burning.
SECTION V- HEALTH HAZARD DATA	
HEALTH HAZARD	
THRESHOLD LIMIT VALUE	
OVER EXPOSURE EFFECTS	
SECTION VI - REACTIVITY DATA	
CHEMICAL STABILITY	Stable
CONDITIONS TO AVOID	Will decompose from exposure and heat as a function of time over 140°C



550 Mallory Way • Carson City, NV 89701

(775) 283-4400 • (800) 475-2214

www.polymerplastics.com

MATERIAL SAFETY DATA SHEET

G-10

SECTION VI - REACTIVITY DATA - CONTINUED

INCOMPATIBLE MATERIALS

DECOMPOSITION PRODUCTS

HAZARDOUS POLYMERIZATIONS

POLYMERIZATION AVOID

Will not occur

SECTION VII - SPILL OR LEAK PROCEDURE

FOR SPILL

WASTE DISPOSAL METHOD

N/A

Landfill

SPECIAL VIII - SPECIAL PROTECTION

RESPIRATORY PROTECTION

Processing equipment should be equipped with an adequate exhaust system. Dust from machining should not be inhaled.

VENTILATION

PROTECTIVE GLOVES

EYE PROTECTION

Protect from flying chips when machining.

OTHER PROTECTIVE EQUIPMENT

HANDLING AND STORAGE

Protective gloves and clothing can be used to prevent coming in contact with the skin.

SECTION IX - SPECIAL PRECAUTIONS

HAZARD CLASS

DOT SHIPPING NAME

REPORTABLE QUANTITY (RQ)

UN NUMBER NA#

NA#

PACKAGING SIZE

Notes:

All information recommendations and suggestions appearing herein concerning this product are based upon data obtained from the manufacturer and/or recognized technical sources. It is the user's responsibility to determine the Safety, Toxicity and suitability of his/her own use, handling and disposal request. Since actual use by others is beyond our control, no warranty, expresses or implied, is made by Polymer Plastics Company L.C. as to effects of such use. The results to be obtained or the safety and toxicity of the product, nor does Polymer Plastics Company L.C. assume any liability arising out of use by others of the product referred to herein. The data in this MSDS relate only to the specific material designated herein and do not relate to use in combination with any other material or in any other process.

REFERENCES: N/A = Not Applicable, N/D = Not Determined, N.D.A. = No Data Available



550 Mallory Way • Carson City, NV 89701

(775) 283-4400 • (800) 475-2214

www.polymerplastics.com



Material Safety Data Sheet

according to Directive EC 1907/2006

Revision: 21-11-11

Page: 1 of 3

Product: Lantor ® Soric XF, SF, TF, LRC

0. Introduction

This document provides a Material Safety Data Sheet (MSDS) for nonwovens on a voluntary basis according to EDANA recommendations (Guidelines/instructions relating to MSDS for nonwovens 10/GV8/422). The MSDS is a means of transferring essential hazard information (including information on transport, handling, storage and emergency actions) from the supplier of a nonwoven product to the recipient of the product. As nonwovens are generally not hazardous, MSDS for nonwovens is not legally requested but must be considered as information. It is inspired from the EC recommendation for MSDS EC 1907/2006.

1. Identification of the product and the company

1.1. Identification of the product(s)

Product name: Lantor Soric XF
Product Code: XF1002, XF1003, XF1004, XF1005, XF1006

Product name: Lantor Soric SF
Product Code: SF1002, SF1003

Product name: Lantor Soric TF
Product Code: TF1015, TF1002, TF1003

Product name: Lantor Soric LRC
Product Code: LRC115, LRC102, LRC103

1.2. Intended use of the product

Liner / core material in FRP-applications.

1.3. Company identification

Company/Plant where information on the product safety is available:

Name : Lantor BV/Lantor®
Address : P.O. Box 45, NL-3900 AA Veenendaal, The Netherlands
Phone number : +31(0) 318 537111
Fax number : +31(0) 318 537399

Department/person responsible for the product safety:

Name : Lantor B.V. Composites
Address : P.O. Box 45, NL-3900 AA Veenendaal, The Netherlands
Phone number : +31(0) 318 537111
Fax number : +31(0) 318 537420

2. Hazards identification

No hazardous product under normal conditions.

Accidental thermal decomposition or melting state can present hazards.

The information contained in this Material Safety Data Sheet has been developed by the Company on the express request of its customers and to the best of its knowledge. Therefore, the Company does not assume any liability with respect to the correctness and/or completeness of the information provided by this Material Safety Data Sheet. The customer in particular shall not be released from his duty to check all safety relevant properties of the delivered nonwovens and to refer to the official texts for full information on the local obligations.

Material Safety Data Sheet

according to Directive EC 1907/2006

Revision: 21-11-11

Page: 2 of 3

Product: Lantor ® Soric XF, SF, TF, LRC

3. Composition / Information on ingredients

Identification of the type of nonwoven product:

- 3.1. *Nonwoven*
Carded web, chemically bonded.
- 3.2. *Nature of the fibre(s)*
Polyester (PES)
- 3.3. *Web surface treatment - Concentration above 1%*
Cured acrylic binder.
- 3.4. *Binder*
Acrylic binder.
- 3.5. *Additives*
Copolymer CAS nr 38742-70-0
Iso-pentane CAS nr 78-78-4
- 3.6. *Other major components - Concentration above 1% - None*
None.
- 3.7. *Chemicals (in relevant concentration) that are in the list of dangerous substances.*
None.

4. First aid measures

- 4.1. *Inhalation*
By inhalation of microspheres, move person to fresh air.
- 4.2. *Skin contact*
No specific measure to be taken.
- 4.3. *Eyes contact*
Eyes should be flushed out with water.
- 4.4. *Ingestion*
Unlikely. In case of ingestion, get medical help.

5. Fire fighting measures

- 5.1. *Suitable extinguishing media*
Water, water/foam, CO₂.
- 5.2. *Extinguishing-media not to be used*
Water in case short-circuiting is the cause of the fire.
- 5.3. *Special exposure hazard*
For flammable and toxic fumes as well as skin contact with molten materials see section 10.
- 5.4. *Special protective clothing for fire-fighter*
No special requirement.

6. Accidental release measures

Not applicable.

7. Handling and storage

Keep Lantor Soric ® in the original package. Store in a cool and well ventilated area. The temperature should be above 0 °C but must not exceed +30 °C.

8. Exposure controls / personal protection

General room ventilation is recommended.

The information contained in this Material Safety Data Sheet has been developed by the Company on the express request of its customers and to the best of its knowledge. Therefore, the Company does not assume any liability with respect to the correctness and/or completeness of the information provided by this Material Safety Data Sheet. The customer in particular shall not be released from his duty to check all safety relevant properties of the delivered nonwovens and to refer to the official texts for full information on the local obligations.

Material Safety Data Sheet

according to Directive EC 1907/2006

Revision: 21-11-11

Page: 3 of 3

Product: Lantor ® Soric XF, SF, TF, LRC

9. Physical and chemical properties

Appearance (the colour of the product as supplied):	Off-white
Odour	: Neutral
pH	: not applicable
Boiling point/boiling range	: not applicable
Melting point/melting range	: 250 – 265 °C (PES fibres)
Decomposition temperature	: 450 °C
Flash point	: not applicable
Flammability	: not easily flammable (see section 10)
Autoflammability (temperature)	: > 450 °C
Explosive properties	: not applicable
Oxidizing properties	: not applicable
Vapour pressure	: not applicable
Relative density	: not applicable
Solubility: - water solubility	: insoluble in water
- fat solubility	: not applicable
Partition coefficient: n.octanol/water	: not applicable

10. Stability and reactivity

The material is chemically stable.

Under thermal decomposition flammable and toxic fumes can be generated. The generation of cleavage and oxidation products is subject to fire conditions. Non burned residues and contaminated water after fire fighting should be disposed of in compliance with official regulations. Molten material should not be allowed to be in contact with the skin to which it can cause burns.

11. Toxicological information

Acute toxicity:	None
Local effect:	None
Chronic short and long term toxicity:	None
Note: Under decomposition conditions; toxic fumes and contaminated water; see section 10.	

12. Ecological information

There is no indication that this material is a risk to the environment. This material is water insoluble.

13. Disposal considerations

As on hazardous solid waste, nonwovens can be disposed of, depending on local legislation, through recycling, incineration or landfill.

14. Transport information

Not classified as hazardous for transport.
Keep the material dry during transport.

15. Regulatory information

None.

16. Other information

None.

The information contained in this Material Safety Data Sheet has been developed by the Company on the express request of its customers and to the best of its knowledge. Therefore, the Company does not assume any liability with respect to the correctness and/or completeness of the information provided by this Material Safety Data Sheet. The customer in particular shall not be released from his duty to check all safety relevant properties of the delivered nonwovens and to refer to the official texts for full information on the local obligations.

APPENDIX G: Gantt Chart

